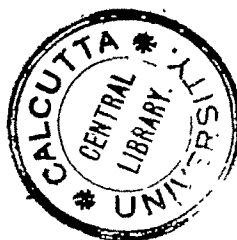
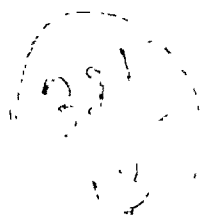


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161	8	pull	hull
268	17*	Borsche Bhar ( <i>ibid.</i> , 1914)	Borsche and Bahr ( <i>ibid.</i> , 1913)
270	6	(quantitative)	6% of theory
	7	-5-bromo-7-amino	-4-bromo-6-amino
371	14*	Found :N, 7.47 requires N, 7.25	Found :N, 7.25 requires N, 7.47
372	26	$C_{17}H_{12}O_8N_2Br$	$C_{17}H_{17}O_8N_2Br$ .

\* From bottom.

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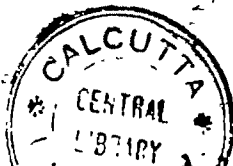
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1947

CONDUCTANCE OF SALTS IN NON-AQUEOUS SOLVENTS. PART I.  
CONDUCTANCE OF SALTS IN TRIETHANOLAMINE

By S. K. BHATTACHARYYA AND S. N. NAKHATE

Conductivities of a number of electrolytes, e.g., tetraethylammonium chloride, tetraethylammonium chlorate, tetramethylammonium chloride, tetramethylammonium chlorate, tetramethylammonium perchlorate, ethylamine hydrochloride, hydrochloric acid, sulphuric acid and sodium, were determined under different experimental conditions using triethanolamine as a solvent. The equations (i) of Debye-Hückel-Onsagar and (ii) of Fuoss and Kraus were tried on the experimental results. Considering the fact that the above equations are valid for strong electrolytes at large dilutions, the results which have been recorded in this part could be explained more or less satisfactorily even though the solutions studied are moderately concentrated. The variation of conductivity with increasing temperature has been found to be quite normal and the plot of  $\log \kappa$  against  $T$  (temperature) passes through a maximum as in most non-aqueous solvents. Walden's rule fails completely in triethanolamine solvent. The mobility of tetraethylammonium ion in triethanolamine solvent has been calculated and found to be 0.0355.

The study of conductance in non-aqueous solutions is of importance not only for understanding the nature of these solutions but also for testing the various theories of conductance that have been developed in this field. Reference may be made to the work done by Franklin *et al.* (*J. Amer. Chem. Soc.*, 1905, 27, 191; *Amer. Chem. J.*, 1888, 23, 277; *J. Phys. Chem.*, 1911, 15, 675, 683; *Z. physikal. Chem.*, 1909, 69, 290), Hartley *et al.* (*Proc. Roy. Soc.*, 1925, A, 109, 351, 1930, A, 126, 84; 1930, A, 127, 228; 1931, A, 132, 427; *J. Chem. Soc.*, 1930, 2488, 2492; 1931, 199, 215; *Ann. Rep. Chem. Soc.*, 27, 326), Walden *et al.* (*Z. physikal. Chem.*, 1924, 114, 275, 287; 1926, 123, 429; 1931, A153, 1; 1929, A144, 262, 395; 1928, A140, 89; 1932, A 160, 337; 1930, A 147, 1) and more recently by Fuoss, Kraus and their collaborators (*J. Amer. Chem. Soc.*, 1933, 55, 21; 1940, 62, 506, 2238) in various solvents, e. g., liquid ammonia, different alcohols, benzonitrile, sulphur dioxide, pyridine, etc. The experimental data have been used to examine critically the theories of Arrhenius (*Z. physikal. Chem.*, 1887, 1, 631), Debye-Hückel (*Physikal. Z.*, 1923, 24, 185, 305; *Trans. Faraday Soc.*, 1927, 23, 334), Onsagar (*Physikal. Z.*, 1926, 27, 388; 1927, 28, 277; *Trans. Faraday Soc.*, 1927, 23, 341), and Fuoss and Kraus (*J. Amer. Chem. Soc.*, 1933, 55, 476, 1019, 2387, 3614; 1935, 57, 1; Kraus, *Trans. Amer. Electrochem. Soc.*, 1934, 66, 179; Fuoss, *Chem. Rev.*, 1935, 17, 27), which are based mostly on data obtained for aqueous solutions.

It has been found that in solvents other than simple alcohols, large deviations from the Debye-Hückel-Onsagar's equation are common. With solvents of low dielectric constants the deviations from Onsagar's equation are universal and become rapidly greater, the smaller the dielectric constant. Extremely interesting results were obtained by Kraus and Fuoss (*J. Amer. Chem. Soc.*, 1933, 55, 21), who studied tetra-isoamylammonium nitrate in mixtures of dioxane and water, with dielectric constants varying from 78.6 to 2.2. Fuoss *et al.* (*loc. cit.*) have developed a theory to explain most of the experimental data in non-aqueous solvents of both high and low dielectric constants.

In the literature we do not find any data for systems where the solvent is very viscous and also where solvent molecules are large or of the same order of magnitude

as the solute molecules. Mention may be made of the studies on the conductance of some organic amine picrates and chlorides in tricresyl phosphate,  $(\text{CH}_3\text{C}_6\text{H}_4\text{O})_3\text{PO}$ , [ $\eta=0.295$  poises at  $40^\circ$  and  $D$  (dielectric constant)=6.92] by Elliot and Fuoss (*J. Amer. Chem. Soc.*, 1939, **61**, 294), and in monoethanolamine,  $(\text{C}_2\text{H}_4\text{OH})\text{NH}_2$ , [ $\eta=0.193$  poises and  $D=37.72$ ] by Brisco and Dirkse (*J. Phys. Chem.*, 1940, **44**, 388).

It is possible that a more complete understanding of the nature of solutions can come only through experimental work extending over a variety of solvents having a wide range of viscosities and dielectric constants, and also a wide range of concentrations.

In this part data for the electrical conductivities of solutions of uni-univalent electrolytes in a very viscous solvent, triethanolamine  $[(\text{C}_2\text{H}_4\text{OH})_3\text{N}]$ , have been recorded. Triethanolamine should behave both as an alcoholic solvent as well as a strong ammoniacal base. It has an extremely high viscosity ( $\eta=8.27$  poises at  $25^\circ$ ) and moderately high dielectric constant ( $D=29.36$  at  $25^\circ$ ).

In the present investigation, conductivity measurements could not be made at large dilutions, due to the fact that accurate null-points could not be obtained with the Wheatstone bridge arrangement used by us.

The equations of Debye-Huckel-Onsagar (i) and of Fuoss and Kraus (ii) have been tried on the experimental results. Considering the fact that (i) and (ii) are valid for strong electrolytes at large dilutions, the results which we have obtained could be explained more or less satisfactorily, even though the solutions studied are moderately concentrated and the sources of error in the measurements are numerous.

The following electrolytes have been studied: (a) tetraethylammonium chloride, (b) tetraethylammonium chlorate, (c) tetramethylammonium chloride, (d) tetramethylammonium chlorate, (e) tetramethylammonium perchlorate, (f) ethylamine hydrochloride, (g) hydrochloric acid, (h) sulphuric acid, and lastly (i) sodium.

## EXPERIMENTAL

For measurement of conductivities, the Kohlrausch method was used. The bridge wire was of the drum type, 470 cm. long, of 7 ohms resistance and having an ebonite hood made by the Leeds and Northrup Co. The scale was graduated to read accurately one in 10,000. An alternating current of a standard frequency of 1000 cycles was supplied by a Leeds and Northrup microphone hammer, operated by a six volt lead accumulator battery, the frequency being controlled by a 1000 cycle tuning fork. The current had some harmonics but their effect was greatly reduced by the tunable telephone used.

Two standard decade dial resistance boxes of Leeds and Northrup, each giving 1-10,000 ohms and two standardised fixed resistances, one of 55,000 and the other of 100,000 ohms were used for known resistances in the bridge circuit, with the tuned telephone set in the detector circuit. The temperature was maintained constant within  $\pm 0.05^\circ$ .

*The Conductivity Cell.*—Being a very hygroscopic liquid and highly alkaline in nature, with a strong tendency to absorb water vapour and carbon dioxide from the atmosphere, triethanolamine must be carefully handled with

as little exposure as possible. It is very viscous and cannot be pipetted or easily transferred in any other way. The range of conductivities to be measured in the same cell was also very wide, being from  $1 \times 10^{-7}$  to  $1 \times 10^{-2}$  mhos. The electrodes should occupy therefore a very large area. The cell used was similar to the one used by Guy and Jones (*Amer. Chem. J.*, 1911, **46**, 131) in their investigation on glycerine. It is made of a neutral glass tube of 30 mm. diameter with a ground-glass cap, through which are passed two glass tubes (carrying the electrodes) sealed rigidly. The electrodes were made of thick platinum plates of 25 mm. diameter; two platinum leads were welded on to the plates and were fused into the glass tubes.

With unplatinised electrodes the sound minimum was not sharp enough for accurate determinations; the electrodes were therefore covered with a fine, velvety black coating of platinum, despite the fact that for alkaline solvents unplatinised electrodes are supposed to give better results.

Livingston, Morgan and Lammert (*J. Amer. Chem. Soc.*, 1923, **45**, 1692; 1924, **46**, 1117) found that the method of cleansing and drying the electrodes was of very great importance, and capable of introducing errors as high as 2 to 3%.

The electrodes were first washed with dilute hydrochloric acid, then followed by washing in running water, distilled water and conductivity water. Finally they were washed with anhydrous alcohol and dried in air. Throughout the course of washing and drying and bringing the cell to the temperature of the thermostat, the electrodes were short circuited by means of a copper wire.

*The Determination of the Cell Constant.*—In most cases the cell constant was determined with two concentrations of KCl, 0.001*N* and 0.1*N* taking usual precautions.

*Manipulation.*—The cell was carefully cleansed, steamed and dried, as mentioned before. The container without the electrodes was weighed, the necessary quantity of solvent was next added and it was quickly reweighed. The ground-glass cap with the electrodes was immediately placed on, any air bubbles entrained in the liquid were removed by gently shaking and warming. The cell was then left in the thermostat for half an hour, after which the conductivity was determined.

From a weighed quantity of the electrolyte contained in a small, cleaned, steamed and dried weighing bottle, a small quantity was transferred quickly into the cell and its weight was determined by difference. The solute was dissolved by gentle shaking and warming; air bubbles were removed as before and the cell was left in the thermostat for half an hour and the conductivity of the solution was determined. This process was repeated with successive additions of the solute to make the solutions of approximately the required concentration.

The above procedure was followed in all cases except with sulphuric acid monohydrate and the sodium derivative of triethanolamine. In the former case, a stock solution of known strength was made by adding a weighed quantity of freshly prepared  $\text{H}_2\text{SO}_4 \cdot \text{H}_2\text{O}$  to pure triethanolamine and weighing out the required quantities of this stock solution into the cell. In the latter case the stock solution was made by reacting the warm solvent with a freshly cut piece of pure sodium metal, washed several times with anhydrous alcohol and finally twice with triethanolamine, the

concentration being afterwards estimated by titration. The solutions were preserved in a ground-stoppered dropping bottle in a vacuum desiccator.

In all cases the conductivities of the solutions were corrected for the conductivity of the solvent which was measured immediately before adding electrolytes.

*The Determination of the Dielectric Constants*—The dielectric constant of triethanolamine was measured in a very simple apparatus used by Nagamani and Jatkar (*J. Indian Inst. Sci.*, 1941, 24A, 81). The dielectric constant for triethanolamine was found to be 22.36.

The viscosity of triethanolamine was determined by Nell and Eclz (*Foqier-Fater. Tech. Teil.*, 1935, 193) who found it to be 8.27 poises at 25°.

#### *Preparation and Purification of the Materials*

*Triethanolamine.*—Reidel's pure triethanolamine was first distilled under a pressure of 2 mm. The middle portion of the distillate was collected and was subjected to the purification process recommended by Germann and Knight (*J. Amer. Chem. Soc.*, 1933, 55, 4150). Triethanolamine was carefully neutralised with concentrated hydrochloric acid at 10–15° and a very slight excess of acid, as shown by litmus paper, was used. In an hour the pure crystals of triethanolamine hydrochloride separated and were filtered off under suction, thoroughly washed with 95% alcohol and dried at 110°. The conversion of the hydrochloride into the free base was effected by sodium hydroxide in isopropyl alcohol as almost all the sodium chloride formed could be separated by cooling; triethanolamine hydrochloride (100 g.) was added to 400 c.c. of isopropyl alcohol containing an equivalent quantity of sodium hydroxide. The mixture was refluxed on a water-bath for 4 hours and allowed to stand overnight. It was then cooled in an ice-bath and the separated sodium chloride filtered on a suction filter. The isopropyl alcohol was then distilled off at atmospheric pressure after which the triethanolamine itself distilled over at about 208° at 10 mm. pressure. The yield was more than 90%. Triethanolamine, thus obtained, was further distilled twice under 2mm. at 175°. A very pale straw coloured oily liquid of sp. gr. 1.1239 was obtained.

B. p. (found)  
176°  
208°

Pressure.  
2 mm.  
10 mm.

B. p. (from literature)  
175°  
208°

The freshly distilled triethanolamine had a specific conductivity of  $2.23 \times 10^{-7}$  mhos which on keeping and with occasional short exposures rose to  $4.3 \times 10^{-7}$  mhos in the course of three months.

*Tetraethylammonium Chloride.*—A pure sample from B.D.H. was recrystallised twice from water and twice from methyl alcohol, as recommended by Hartley *et al.* (*loc. cit.*). It was dried by heating it to 80° and kept in a desiccator under vacuum.

*Tetraethylammonium Chlorate.*—Pure crystallised barium chlorate was treated with an equivalent amount of pure silver sulphate. The mixture after boiling was filtered. The filtrate, free from sulphate, was then used for carefully neutralising a solution of tetraethylammonium chloride using potassium chromate as an external indicator. The silver chloride was separated by filtration, the tetraethylammonium chlorate was crystallised from the filtrate. It was then recrystallised from water and

dried as above. It was tested for chloride and sulphate and was found to be free from them.

*Tetramethylammonium chloride and chlorate* were prepared in the same way as the corresponding tetraethyl salts.

*Tetramethylammonium Perchlorate*.—Pure silver nitrate was treated with pure caustic soda, the precipitated silver oxide was filtered and washed free of alkali. A slight excess of oxide was then heated with 60% perchloric acid, the solution of silver perchlorate was then filtered and evaporated till crystals began to form. The liquor was cooled and crystals separated by filtration. It was recrystallised from benzene and dried at 120° for 12 hours. The salt was then prepared by double decomposition as above.

*Ethylamine Hydrochloride*.—B.D.H. pure sample was recrystallised from water twice and dried at 80° in vacuum.

*Sulphuric acid monohydrate* ( $\text{H}_2\text{SO}_4 \cdot \text{H}_2\text{O}$ ) was prepared by mixing A.R. fuming acid with A.R. redistilled 95% acid in a specially designed conductivity cell until the proper conductivity corresponding to the monohydrate was observed.

The solution of sodium derivative was prepared as already stated.

*Triethanolamine hydrochloride* was prepared by neutralising a cooled solution of pure triethanolamine with concentrated hydrochloric acid. The product was recrystallised from water and dried at 120°, m. p. 177°.

The experimental data are recorded in Tables I-X. In the tables the vertical column I gives the concentration of the electrolyte in g. equivalent per litre ( $c$ ) and column II, equivalent conductivity ( $\lambda_c$ ).

*Extrapolation for  $\lambda_0$* .—The Debye-Huckel-Onsager's equation has been applied to get an approximate value of  $\lambda_0$  in every case. For this,  $\lambda_c$  was plotted as ordinate against  $\sqrt{c}$  (Fig. 1). From these curves  $\lambda_0$  was obtained by extrapolating to zero concentration of the electrolyte. As Onsager's equation gives correct values of  $\lambda_0$  only for strong electrolytes at large dilution, the values of  $\lambda_0$  obtained in the present investigation where only moderate concentrations were used, may not be accurate.

The slope of each curve was calculated and recorded as  $x_{\text{obs}}$ . The Debye-Huckel-Onsager's equation for uni-univalent electrolytes may be represented by  $\lambda_c = \lambda_0 - x\sqrt{c}$  where  $x$  is the theoretical slope of the curve and is equal to

$$\left\{ \frac{5.78 \times 10^6}{(DT)^{\frac{3}{2}}} \lambda_0 + \frac{58.0}{\eta \cdot (DT)^{\frac{1}{2}}} \right\} \sqrt{2}$$

For triethanolamine at 25°, where  $\eta = 8.27$  poises and  $D = 29.36$ ,

$$x = \lambda_0 + 0.1059.$$

The theoretical slope,  $x_{\text{ons}}$ , was calculated in every case and the percentage deviation  $\delta$ , was then calculated as

$$\delta = \frac{x_{\text{obs}} - x_{\text{ons}}}{x_{\text{ons}}} \cdot 100.$$

At the top of each table the values of  $\lambda_0$ ,  $x$  and  $\delta$  are given. Fuoss and Kraus method was also tried to get more accurate values of  $\lambda_0$  and  $\gamma$  in case where the  $\lambda_0 - \sqrt{c}$  plot

was not a straight line. According to Fuoss and Kraus the conductance of a binary electrolyte as a function of concentration may be represented by

$$\lambda_c = \gamma (\lambda_0 - x\sqrt{c\gamma}) \quad \dots \quad (i)$$

exactly up to the concentration at which specific interactions of higher order than pair-wise become appreciable. (This concentration is of the order of magnitude  $3.2 \times 10^{-7} D^3$  at  $25^\circ$  where  $D$ =dielectric constant of the solvent). If we know  $\lambda_c$  and  $x$ , and measure  $\lambda_c$  as a function of  $c$ , equation (i) permits us to determine  $\gamma$ , the degree of dissociation as a function of  $c$ . Instead of solving equation (i) by algebraic method, the method of successive approximation was adopted by Fuoss and Kraus (*loc. cit.*) which may be briefly described thus :

By introducing a new variable  $z$ , defined as

$$z = x\lambda_0^{-\frac{3}{2}} \sqrt{c\lambda_c} \quad \dots \quad (ii)$$

where  $x$ =Onsagar's slope,  $\lambda_0$ =limiting conductance,  $\lambda_c$  and  $c$  have their usual significance, equation (i) may be rewritten as

$$\gamma = \frac{\lambda_c}{\lambda_0} \bigg/ F(z) \quad \dots \quad (iii)$$

where 
$$F(z) = \frac{4}{3} \cos^2 \frac{1}{3} \cos^{-1} \left( -3 \sqrt{3} \frac{z}{2} \right). \quad \dots \quad (iv)$$

In order to obtain  $\lambda_0$  from conductance data,  $\lambda_0^-$  obtained by the extrapolation of  $\lambda_0 - \sqrt{c}$  curve was taken. With this tentative value of  $\lambda_0^-$ ,  $z$  was calculated using equation (ii),  $F(z)$  was found from equation (iv) and used in evaluating  $\gamma$  using equation (iii) and then the activity coefficient was calculated from

$$-\log 10 f_{\pm}^2 = \beta \sqrt{c\gamma} / 1 + \delta \sqrt{c\gamma} \quad \dots \quad (v)$$

where 
$$\beta = 0.4343 \cdot \frac{e^2}{2DkT} \left( \frac{8\pi Ne^2}{1000DkT} \right)^{\frac{1}{2}} \quad \text{and} \quad \delta = \left( \frac{8\pi Ne^2}{1000DkT} \right)^{\frac{1}{2}} a$$

[Here  $e = 4.770 \times 10^{-10}$  e.s.u. ;  $N = 6.06 \times 10^{23}$  ;  $k$ =Boltzmann constant  $= 1.371 \times 10^{-18}$  erg/degree ;  $D$ =dielectric constant of the solvent ;  $T$ =absolute temperature ;  $a$ =ionic radius]

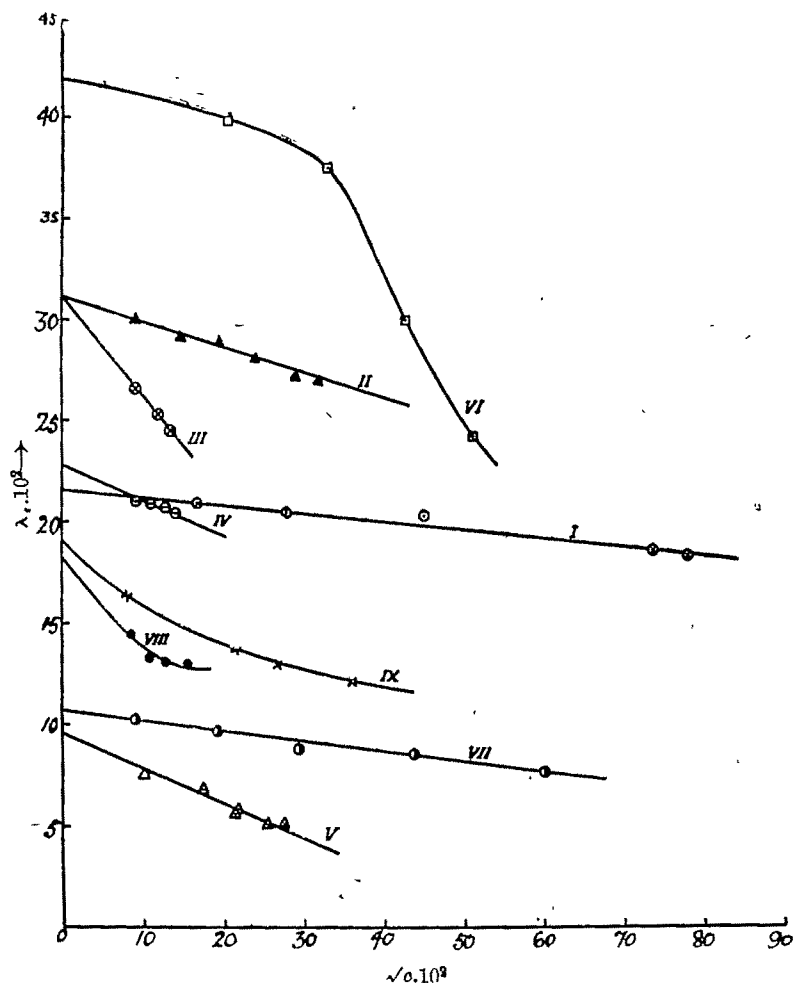
Finally  $F(z)/\lambda_c$  was plotted against  $c\lambda_c f_{\pm}^2/F(z)$

This method was tried with all the electrolytes not giving a straight line plot of  $\lambda_c - \sqrt{c}$ .

Usual  $\gamma$ ,  $z$  and  $F(z)$  values could be obtained in the dilute region only, the critical concentration in the case of triethanolamine being  $8.0 \times 10^{-3}$  g. equivalents. Finally  $F(z)/\lambda_c$  was plotted against  $c\lambda_c f_{\pm}^2/F(z)$ . For only two or three concentrations in the dilute region, a straight line was obtained, with intercept  $1/\lambda_0$  from the relation

$$\frac{F(z)}{\lambda_c} = \frac{1}{k\lambda_0^2} \cdot \frac{c\lambda_c f_{\pm}^2}{F(z)} + \frac{1}{\lambda_0}$$

Fig. 1



Curves I-IX refer respectively to  $\text{Et}_4\text{NCl}$ ,  $\text{Et}_4\text{NClO}_3$ ,  $\text{EtNH}_2\cdot\text{HCl}$ ,  $\text{HCl}$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{Na}$ ,  $\text{Me}_4\text{NCl}$ ,  $\text{Me}_4\text{NClO}_3$  and  $\text{Me}_4\text{NClO}_4$ .

$\lambda_0$  thus found is given at the head of the tables.

TABLE I

Electrolyte:  $\text{Et}_4\text{NCl}$ .  
 $\lambda_0 = 0.216$ .  $T = 25^\circ$ .  $\alpha_{\text{obs}} = 0.3219$ .  $\alpha_{\text{obs}} = 0.04$ .  
 $\delta = -87.6\%$

$c \cdot 10^3$	$\lambda_c \cdot 10^3$
28.5	20.95
78.45	20.5
204.0	20.40
545.0	18.77
609.8	18.5

TABLE II

Electrolyte:  $\text{Et}_4\text{NClO}_3$ .  
 $\lambda_0 = 0.311$ .  $T = 25^\circ$ .  $\alpha_{\text{obs}} = 0.4169$ .  $\alpha_{\text{obs}} = 0.128$ .  
 $\delta = -69.3\%$

$c \cdot 10^3$	$\lambda_c \cdot 10^3$
8.41	30.01
21.27	29.16
38.50	28.98
57.89	28.08
84.68	27.26
101.70	27.02

TABLE III

Electrolyte:  $\text{Me}_4\text{NCl}$ .  
 $\lambda_0 = 0.106$ .  $T = 25^\circ$ .  $\alpha_{\text{obs}} = 0.2116$ .  $\alpha_{\text{obs}} = 0.046$ .  
 $\delta = -78.3\%$

$c \cdot 10^3$	$\lambda_c \cdot 10^3$
7.805	10.23
37.25	9.594
86.56	8.784
192.7	8.570
360.8	7.534

TABLE IV.

Electrolyte:  $\text{Me}_4\text{NClO}_3$ .  
 $T = 25^\circ$ .  $\alpha_{\text{obs}} = 0.2879$ .  
 $\alpha_{\text{obs}} = 0.44$ .  $\lambda_0 = 0.182$ .  
 $\delta = +52.8\%$

$c \cdot 10^3$	$\lambda_c \cdot 10^3$
7.06	14.47
11.18	13.31
16.17	13.15
24.27	12.97

TABLE V

Electrolyte :  $\text{Me}_4\text{NClO}_4$ .  
 $\lambda_o = 0.189$ ,  $x_{\text{ons}} = 0.2955$ .  
 $x_{\text{obs}} = 0.30$ ,  $T = 25^\circ$ .  
 $\delta = +1.5\%$

$c.10^3$	$\lambda_o.10^3$
6.285	16.4
46.33	13.73
72.40	12.99
130.30	12.18

TABLE VI

Electrolyte :  $\text{HCl}$  (as triethanolamine hydrochloride).  $\lambda_o = 0.228$ .  
 $T = 25^\circ$ ,  $x_{\text{ons}} = 0.3339$ .  
 $x_{\text{obs}} = 0.18$ ,  $\delta = -46.0\%$

$c.10^3$	$\lambda_o.10^3$
8.561	20.97
12.01	20.96
16.02	20.78
19.74	20.40

TABLE VII

Electrolyte :  $\text{H}_2\text{SO}_4 \cdot \text{H}_2\text{O}$ .  
 $\lambda_o = 0.096$ ,  $T = 25^\circ$ ,  $x_{\text{ons}} = 0.2019$ .  $x_{\text{obs}} = 0.1841$ .  
 $\delta = -8.8\%$

$c.10^3$	$\lambda_o.10^3$
10.23	7.513
28.70	6.674
45.83	5.751
64.27	5.024
74.74	5.053

TABLE VIII

Electrolyte :  $\text{Na}$  as  $(\text{C}_2\text{H}_4\text{OH})_3\text{N} \cdot \text{C}_2\text{H}_5\text{ONa}$   
 $T = 25^\circ$ ,  $\lambda_o = 0.4184$ ,  $x_{\text{ons}} = 0.5243$ .  $x_{\text{obs}} = 0.08$ .  
 $\delta = -84.7\%$

$c.10^3$	$\lambda_o.10^3$
50.36	39.88
110.00	37.52
182.70	30.04
260.5	24.25

### $\lambda_o$ and Viscosity

The approximate constancy  $\lambda_o \eta_o$ , which is known as Walden's rule (*Z. physikal. Chem.*, 1906, 55, 207; 1912, 78; 257) has been applied to the experimental results in triethanolamine. The products  $\lambda_o \eta_o$ , obtained with different electrolytes in triethanolamine are compared with the products obtained in other solvents of different viscosities at  $25^\circ$  as shown in Table IX.

TABLE IX

Solvent.	$\lambda_o \eta_o$	Electrolyte.	Solvent.	$\lambda_o \eta_o$	Electrolyte.
Triethanolamine	1.786	$\text{Et}_4\text{NCl}$	Triethanolamine	0.794	$\text{H}_2\text{SO}_4 \cdot \text{H}_2\text{O}$
"	0.984	$\text{Me}_4\text{NCl}$	Ethylalcohol	0.549	$\text{Me}_4\text{NCl}$
"	2.570	$\text{Et}_4\text{NClO}_3$	"	0.559	$(\text{C}_2\text{H}_5)_4\text{N-picrate}$
"	1.505	$\text{Me}_4\text{NClO}_3$	Pyridine	0.637 ( $20^\circ$ )	$\text{NaI}$
"	1.583	$\text{Me}_4\text{NClO}_4$	Nitromethane	0.77	$\text{KI}$
"	2.570	$\text{Et}_4\text{N} \cdot \text{HCl}$	Water	1.00	$\text{Et}_4\text{NI}$
"	1.886	$(\text{C}_2\text{H}_4\text{OH})_3\text{N} \cdot \text{HCl}$	Glycol	1.32	$\text{Et}_4\text{NI}$

Walden's rule, as originally proposed is empirical, but it has been shown subsequently that this rule is a direct consequence of the application of Stoke's law to the motion of ions. Very large spherical ions would be nearly free from solvation because of the low charge density on their surfaces and the magnitude of their radii would be independent of the nature of the solvent. Such ions would most nearly approximate the ideal condition of spheres moving through homogeneous media, as required by Stoke's law. Ions of small size or of unsymmetrical shape or distribution of charge would be expected to exhibit widest departure from Walden's rule. From the above table we find that Walden's rule fails completely in triethanolamine. In general, as Walden himself pointed out, the deviations are greatest in solvents of high viscosity and also in those of high dielectric constant.



*Ionic Mobility in Triethanolamine*

Walden (*loc. cit.*) has shown that the product of ionic mobility at infinite dilution ( $\lambda^\circ$ ) and the viscosity ( $\eta_0$ ) of the solvent at the same temperature, is practically independent of temperature and exhibits less than two-fold variation from solvent to solvent, the product being greatest in water. With  $(C_2H_5)_4N^+$  and picrate ions, however, the product  $\lambda^\circ \eta_0$  is independent of the nature of solvents.

Taking a mean value of  $\lambda^\circ \eta_0 = 0.294$  at  $25^\circ$  in the case of  $(C_2H_5)_4N^+$  ion, we have the mobility of  $Et_4N^+$  ion in triethanolamine =  $0.294/8.27$  as  $0.0355$ .

*Conductivity and Temperature*

The effect of temperature on conductivity has been studied by measuring the conductivity of tetramethylammonium perchlorate at different temperatures by making the usual solvent correction for every reading and at every temperature studied. The results are summarised in Table X.

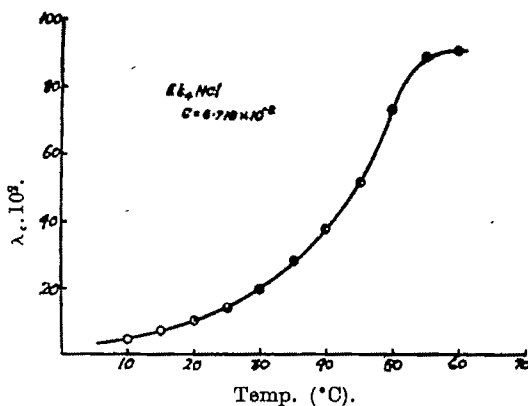
TABLE X

Conc. of tetramethylammonium perchlorate =  $6.719 \times 10^{-2} N$ .

$T$	$10^\circ$	$15^\circ$	$20^\circ$	$25^\circ$	$30^\circ$	$35^\circ$	$40^\circ$	$45^\circ$	$50^\circ$	$55^\circ$	$60^\circ$
$\lambda_c \cdot 10^2$	4.5	7.21	10.29	13.32	20.03	27.76	37.67	51.4	68.1	89.83	91.37

The results are plotted by taking  $T$  as abscissa and  $\lambda_c$  as ordinate (Fig. 2.). The general trend of the above is quite normal and the curve seems to pass through a maximum, as in most non-aqueous solvents.

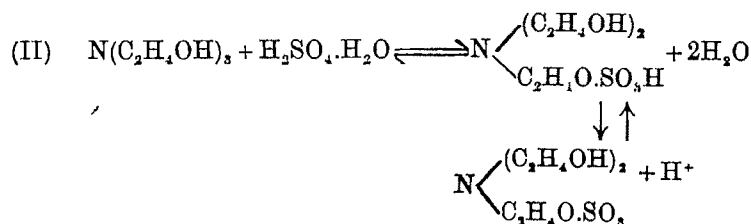
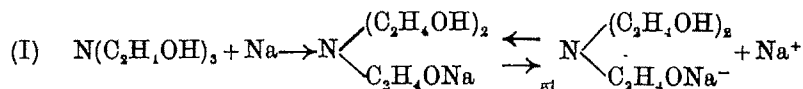
FIG. 2.



## DISCUSSION

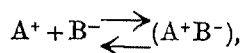
From Tables I to VIII and Fig. 1 we find that in the case of tetramethylammonium chlorate, tetramethylammonium perchlorate and sodium, straight lines of  $\lambda_c - \sqrt{c}$  plots could not be obtained as demanded by Debye-Huckel-Onsagar's equation. With the other electrolytes, however, straight lines could be obtained. As pointed out before, Onsagar's limiting equation should give straight lines only in the dilute regions. At rather high concentrations, as have been used in the present investigation, the limiting equation of Onsagar can no longer be valid, so that even if the mobility change at higher concentrations be still governed by the same laws, it cannot be calculated with the same degree of accuracy. Further, there is the probability that as we pass from dilute to concentrated solutions, additional factors, which could be completely ignored at large dilutions, will eventually become important. One such factor is the viscosity of the solution and the effect of this is difficult to compute; apart from its direct influence on ionic speeds, it will interfere to some extent at high concentrations with the effect of the interionic forces. An additional possibility is the formation of complex ion.

As usual, it has been tried to get values of  $\lambda_0$  by extrapolation in all cases either from the free-hand curves, or the straight lines as the case may be. However, we do not claim any degree of accuracy in the values of  $\lambda_0$  thus obtained for reasons cited before. It has been assumed that the electrolytes studied are all uni-univalent. For the ionisation of sodium derivatives, and  $\text{H}_2\text{SO}_4 \cdot \text{H}_2\text{O}$ , the following equations have been assumed.



It will be noticed that the deviations from the limiting square-root law are very large with some electrolytes. For tetramethylammonium perchlorate and  $\text{H}_2\text{SO}_4 \cdot \text{H}_2\text{O}$ , the deviations are comparatively very small. These deviations point to the incomplete dissociation or ionic complexes in most of the electrolytes studied.

Next the equations deduced by Fuoss and Kraus by making the necessary corrections for both mass action effects as well as ion-atmospheric effects have been tried. These equations, which are based on the binary equilibrium



should fail at concentrations higher than a critical concentration, determined by the dielectric constant and temperature of the solvent. At  $25^\circ$ ,  $c_0 = 3.2 \times 10^{-7} D^3$ , where  $c_0$  = critical concentration. For triethanolamine, this concentration should be

$8.0 \times 10^{-3} M$  at  $25^\circ$ . For tetramethylammonium chlorate and perchlorate and also for sodium,  $\lambda_\infty$  values have been extrapolated from the curves  $F(z)/\lambda_\infty - c\lambda_\infty f_1/F(z)$  which are drawn with only two or three points in the neighbourhood of the critical concentration.

Table IX shows that the values of  $\lambda_\infty \eta_\infty$  are, for all the electrolytes studied, greater than 0.70, a value obtained in most of the non-aqueous solvents of low viscosity.

As a tentative explanation we may suggest like Elliott and Fuoss (*loc. cit.*) that the effective greater mobility in triethanolamine is due to slipping. In solvents of low viscosity, *e.g.* ethylene chloride, acetone etc, the solute ions are much larger than the solvent molecules and the physical approximation that the solvent is a continuous medium is to some extent, at least, justified. In triethanolamine, on the other hand, the approximation seems no longer permissible, because solvent molecules are now larger than or are of the same order of magnitude as the ions and for that reason a modification of the simpler hydrodynamics becomes necessary. The most obvious correction that is necessary is to make allowance for the greater probability of a small ion passing through large solvent molecules of certain configuration without displacing them and this slipping will naturally lead to an effective greater mobility.

From Table X we find that the equivalent conductivity reaches a maximum value and then it decreases with increasing temperature (Fig.2). In the main these changes are undoubtedly due to changes in the viscosity and dielectric constant of the solvent. The large increase in equivalent conductivity is due to the increased ionic mobility as a result of lowering of viscosity and the simplification of complexes. But with increase in temperature, the dielectric constant, and hence the dissociation power also diminishes and from the maximum point onwards, the latter effect outweighs the former and it is known that as its critical temperature is approached, the solvent becomes almost a perfect insulator.

The authors wish to express their thanks to Sir J. C. Ghosh for his kind help and advice and to Mr. M. S. Muthanna M. Sc., for his kind help in preparing some of the organic compounds used in this investigation. Thanks are due to Dr. S. K. K. Jatkar for his kind help in making the dielectric measurements.

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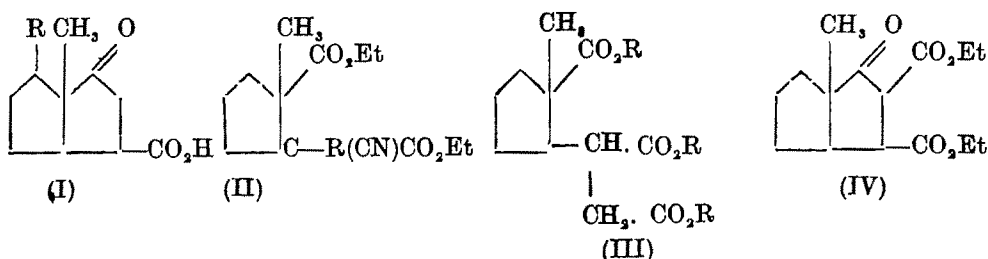
SYNTHETIC INVESTIGATIONS ON STEROLS, BILE ACID, HORMONE,  
ETC. PART V. SYNTHESIS OF 7-METHYL-0:3:3-BICYCLO-  
OCTANNE-1-ONE-3-CARBOXYLIC ACID

BY P. BAGCHI AND D. K. BANERJEE

A synthesis of 7-methyl-0:3:3-bicyclooctane-1-one-3-carboxylic acid has been described. By the oxidation of the above ketonic acid, the locking of the fused carbon rings has been shown to be *cis*.

Wieland and Schlichting (*Z. physiol. Chem.*, 1924, 134, 276) obtained through the oxidative degradation of desoxycholic acid, a tetracarboxylic acid  $C_{16}H_{24}O_8$ , which on pyrolysis gave rise to a keto-dicarboxylic acid of the composition  $C_{17}H_{22}O_6$  to which they assigned the structure (I,  $R = C_4H_9 \cdot CO_2H$ ). As a preliminary to the synthesis of the above pyroketo-acid, we have synthesised the simpler keto-acid (I,  $R = H$ ).

Ethyl 2-methyl-2-carbethoxycyclopentylcyanoacetate (II,  $R = H$ ) has been prepared by the reduction of ethyl 2-methyl-2-carbethoxycyclopentylidene-cyanoacetate (Linstead and Errington, *J. Chem. Soc.*, 1938, 666; cf. Banerjee, *Science & Culture*, 1944, 9, 456) with aluminium amalgam in an ethereal solution. The yield of the above reduction, however, could be considerably improved upon that obtained by Linstead *et al* (*loc. cit.*) either by submitting the aluminium sludge, after filtration, to extraction with ether in a Soxhlet apparatus or by treating the reaction mixture with ice-cold dilute mineral acid and then extraction with solvent. Potassio salt of (II,  $R = H$ ) is condensed with ethyl bromoacetate in an alcoholic solution, when diethyl  $\alpha$ -cyano- $\alpha$ -(2-methyl-2-carbethoxycyclopentyl)succinate (II,  $R = CH_2 \cdot CO_2Et$ ) is obtained, which on hydrolysis yields 2-methyl-2-carboxycyclopentylsuccinic acid (III,  $R = H$ ). The triethyl ester (III,  $R = Et$ ) smoothly undergoes Dieckmann's condensation to afford ethyl 7-methyl-0:3:3-bicyclooctane-1-one-2:3-dicarboxylate (IV) which gives an intense ferric chloride coloration in an alcoholic solution. 7-Methyl-0:3:3-bicyclooctane-1-one-3-carboxylic acid is obtained by the hydrolysis of the  $\beta$ -ketonic ester as a viscous oil. The keto-acid (I,  $R = H$ ) on oxidation with concentrated nitric acid yields a solid acid, which after several crystallisations from acidulated water melts at  $124-26^\circ$ . Mixed melting point with an authentic sample of *cis*-1-methylcyclopentane-1:2-dicarboxylic acid (Dutta, *J. Indian Chem. Soc.*, 1940, 17, 611; Bachmann *et al.*, *J. Amer. Chem. Soc.*, 1941, 63, 1261) shows no depression (melting point of the above *cis* acid was found to depend considerably on the rate of heating). The formation of the *cis*-locking in this case is in conformity with our previous observation in the preparation of 7-methyl-0:3:3-bicyclooctane-1-one (Banerjee, *loc. cit.*).



EXPERIMENTAL

*Ethyl 2-Methylcarbethoxycyclopentylidene-cyanoacetate*.—Previously Linstead and

Errington (*loc. cit.*) prepared this compound from ethyl 2-methylcyclopentanone-2-carboxylate and ethyl cyanoacetate under 4000 atm. pressure in 20% yield. Utilising the modified method of Cope *et al.* (*J. Amer. Chem. Soc.*, 1941, **63**, 3452), we obtained the condensation product in much improved yield.

Ethyl cyanoacetate (21 g.), ethyl 2-methylcyclopentanone-2-carboxylate (32 g.), ammonium acetate (10 g.), glacial acetic acid (12 c. c.) and dry benzene (50 c. c.) were refluxed in a 500 c. c. flask, to which a water separator (Cope *et al. loc. cit.*) had been attached, until no further water separated. Further ammonium acetate (5 g.) and acetic acid (10 c. c.) were added and again refluxed for 8 hours, when very little water was found to separate. Reaction mixture was then transferred to a separating funnel with benzene and repeatedly washed with water. Benzene was removed and the residue fractionated when 32.3 g. of the condensation product boiling  $150^{\circ}/4$  mm. were obtained together with a forerun of unchanged materials.

*Ethyl 2-Methyl-2-carbethoxycyclopentylcyanoacetate.*—Aluminium amalgam (32 g.) was covered with an ethereal solution (500 c.c.) of the above unsaturated cyano-ester and left at the room temperature for 7 days with frequent addition of a small quantity of water. Aluminium sludge was filtered off and was extracted with ether in a Soxhlet apparatus. Ethereal solutions were combined and the solvent was removed. The residue boiled at  $138^{\circ}/3.5$  mm. and the yield was 31 g. Similar yield was also obtained when the ethereal solution together with the sludge was poured into an ice-cold dilute mineral acid and well shaken until the mixture considerably cleared up, then the ether layer was separated and the aqueous layer was re-extracted with ether and the combined ethereal solution was worked up in the usual manner.

*Diethyl  $\alpha$ -Cyano- $\alpha$ -(2-methyl-2-carbethoxypentyl)-succinate.*—Potassium (2.3 g.) pulverised under dry toluene (30 c. c.) was treated in an ice-bath with absolute alcohol (12 c.c.) added dropwise and left overnight. Ethyl 2-methyl-2-carbethoxycyclopentylcyanoacetate (15.6 g.) was slowly added to it with cooling and the mixture allowed to stand for  $1\frac{1}{2}$  hours. Ethyl bromoacetate (7 c. c.) was next added to the potassium-salt thus formed, when potassium bromide separated out in the cold. The reaction mixture was heated on a water-bath for 4 hours, followed by refluxing for 8 hours. Water was added to it after cooling and the product after addition of some ether was twice washed with water, and dried. Solvents were removed and the residue was distilled in vacuum, when about 20 g. of the condensation product were obtained, b.p.  $207^{\circ}/7.8$  mm. (Found: C, 61.5; H 7.4.  $C_{18}H_{27}O_6N$  requires C, 61.2; H, 7.6 per cent).

*2-Methyl-2-carboxycyclopentylsuccinic Acid.*—Diethyl  $\alpha$ -cyano- $\alpha$ -(2-methyl-2-carbethoxycyclopentyl)-succinate (18 g.) was refluxed with concentrated hydrochloric acid (110 c.c.) for 50 hours, when white crystals were found to separate out in the cold. Crystals were filtered off and recrystallised from dilute hydrochloric acid, m.p.  $208-11^{\circ}$  with previous shrinking at  $200^{\circ}$ . (Found: C, 53.82; H, 6.67.  $C_{11}H_{16}O_6$  requires C, 54.1; H, 6.6 per cent).

*Diethyl 2-Methyl-2-carbethoxycyclopentylsuccinate.*—The filtered hydrochloric acid solution obtained above was completely evaporated to dryness on a water-bath in a basin. The crude acid together with ammonium chloride was esterified by refluxing with alcohol (50 c.c.) and sulphuric acid ( $d$  1.84, 7 c.c.) for 36 hours. Ice-cold water

was added to it and extracted with ether. The ethereal layer was washed with water, ice-cold caustic potash solution and then again with water, and dried. Ether was removed and the residue on distillation boiled at  $170^{\circ}/5$  mm. The alkaline washing was acidified in the cold and the separated oil was extracted with ether, the solvent was removed and the residue, after being dried in vacuum, was re-esterified by the alcohol-sulphuric acid method. It was worked up in the usual way bringing the total yield of the tri-ester to 12 g. (Found: C, 62.10; H, 8.36.  $C_{17}H_{28}O_6$  requires C, 62.19; H, 8.53 per cent).

*Ethyl 7-Methyl-0:3:3-bicyclooctane-1-one-2:3-dicarboxylate*.—Triethyl ester (III, R=Et; 10.4 g.) was refluxed with sodium dust (1.5 g) in dry benzene for 3 hours, when whole of the metallic sodium disappeared. Ice-cold dilute hydrochloric acid was poured into the cooled reaction mixture. Benzene layer was separated and the aqueous layer extracted with ether. Combined ether-benzene solution was successively washed with water, sodium bicarbonate solution and water. Solvents were removed. On distillation in vacuum the product boiled at  $168^{\circ}/9$  mm., yield 6.5 g. (Found: C, 64.15; H, 7.86.  $C_{15}H_{22}O_6$  requires C, 63.83; H, 7.8 per cent).

*7-Methyl-0:3:3-bicyclooctane-1-one-3-carboxylic Acid*.—Ethyl 7-methyl-0:3:3-bicyclooctane-1-one-2:3-dicarboxylate (6 g.) was refluxed with 20% sulphuric acid (50 c.c.) for 16 hours. The cooled acid solution was thoroughly extracted with ether and the residue left after evaporation of the solvent boiled at  $162-165^{\circ}/5$  mm., yield 3 g. (Found: C, 65.2; H, 7.9.  $C_{16}H_{14}O_4$  requires C, 65.9; H, 7.7 per cent).

The semicarbazone, prepared in the usual way after purification by means of crystallisation, melted at  $234^{\circ}$ . (Found: C, 54.9; H, 6.92.  $C_{11}H_{11}O_3N_3$  requires C, 55.2; H, 7.1 per cent).

*Oxidation of the Keto-acid* (I; R=H).—7-Methyl-0:3:3-bicyclooctane-1-one-3-carboxylic acid (1.8 g.) was heated with nitric acid ( $d$  1.4, 14 c.c.) on a boiling water-bath for 1 hour. It was then refluxed with an addition of water for further 1 hour. The solution was evaporated as much as possible on a water-bath and then left in an evacuated desiccator on caustic potash, when the product crystallised out. Adhering gum was removed on a porous plate and the product was crystallised several times from dilute hydrochloric acid, when it melted at  $124-26^{\circ}$ . The m.p. was not depressed on an admixture of *cis*-1-methylcyclopentane-1:2-dicarboxylic acid. (Found: C, 56.0; H, 7.0.  $C_8H_{12}O_4$  requires C, 55.8; H, 6.99 per cent).

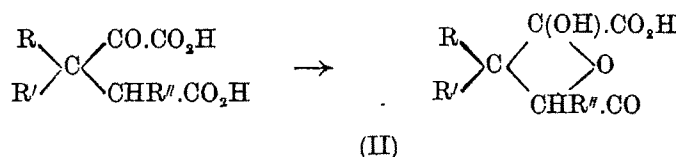
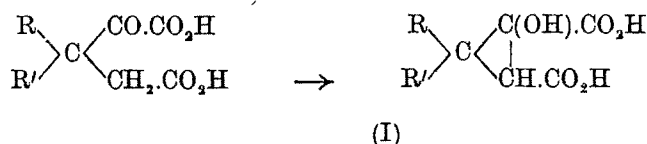
The authors, thanks are due to Prof. P. C. Mitter for his kind interest. They are indebted to Dr. P. C. Dutta for the supply of the authentic specimen of *cis*-1-methylcyclopentane-1:2-dicarboxylic acid and also to Mr. N. Ghosh, for carrying out microanalysis.

# KETO-LACTOL TAUTOMERISM. PART VII. SYNTHESSES OF *CYCLO*- HEXANE-1-ACETYL-1-ACETIC ACID, *CYCLO*HEXANE-1-BENZOYL- 1-ACETIC ACID AND OTHER RELATED COMPOUNDS AND EXAMINATION OF THEIR BEHAVIOUR

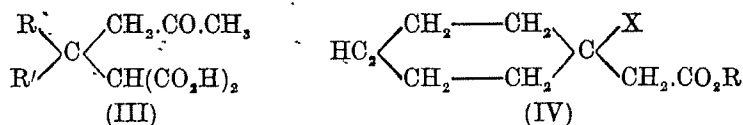
BY MUHAMMAD QUDRATI-KHUDA AND KHITISH CHANDRA BHATTACHARYA

*cyclo*Hexane-1-acetyl-1-acetic acid has been synthesised. It does not show any tautomeric tendency of either keto-lactol or keto-cyclol type. No tendency for the said tautomerism could be induced by substitution of the acetyl group by either a benzoyl or anisoyl group. *cyclo*Hexane-1-oxalyl-1-acetic acid has been claimed to show tautomerism of the keto-cyclol type. In the light of the above observation a re-examination of this acid become necessary. The acid has been synthesised and put to the known tests but it fails to exhibit any tautomeric tendency.

Although occasional references appear in the literature to the tendency of  $\gamma$ -ketonic acids to show a remarkable capacity for ring chain tautomerism of keto-cyclol type (I) (Deshapande and Thorpe, *J. Chem. Soc.*, 1922, 121, 1438; Singh and Thorpe, *ibid.*, 1923, 123, 113) and of keto-lactol type (II) (Rothstein and Shoppee, *J. Chem. Soc.*, 1927, 532); the problem does not appear to have been systematically studied.



The examination of the ketonic acids of the type (III) (Qudrat-i-Khuda, *J. Chem. Soc.*, 1928, 201, 713) suggests that valuable information can be gathered from a study of the  $\gamma$ -ketonic acids of the type (IV, where 'X' can be different substituents such as methyl, carboxyl, phenyl or anisoyl group).

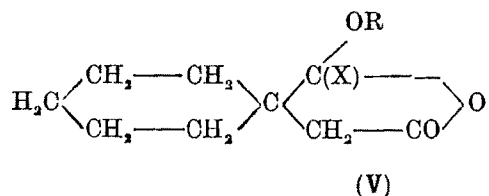


With this idea an extensive study of various compounds of the series has been made. Some of these only constitute the subject matter of the present communication.

*cyclo*Hexane-1-acetyl-1 acetic acid (IV, X=COCH<sub>3</sub>; R=H) has been prepared from *cyclo*hexane-1-carboxy-1-acetic acid (IV, X=COOH; R=H) by the method of Lapworth and Mc Rae (*J. Chem. Soc.*, 1922, 121, 2741). The anhydride of this acid through its methyl hydrogen ester gives an acid chloride, which could be converted into methyl *cyclo*hexane-1-acetyl-1-acetate (*cf.* Rothstein and Thorpe, *J. Chem. Soc.*, 1926, 2011) with zinc methyl iodide.

The ketonic acid (IV, X=CO.CH<sub>3</sub>; R=H,) is allowed to be acted upon by a concentrated solution of potassium hydroxide but no tautomerism of the keto-cyclol type could be observed here. The acid also remains unaffected by either acetyl chloride or

acetic anhydride, both of which do not yield the acetyl lactol (V, R=Ac ; X=CH<sub>3</sub>) as they do with ordinary laevulinic acid.



The configuration of the ketonic acid has been settled by its conversion into the semicarbazone. It does not undergo the change into ethoxy ester (V, R=Et ; X=Me) on esterification and on Clemmensen reduction the ketonic compound changes into *cyclohexane-1-ethyl-1-acetic acid* (IV, X=Et ; R=H).

This lack of tendency of the acid to show the tautomeric capacity, which *cyclohexane-1-oxalyl-1-acetic acid* exhibits to a very remarkable degree (Lanfear and Thorpe, *J. Chem. Soc.*, 1923, 123, 2865), we are led to believe that the change of methyl group for a negative group may develop the expected capacity. We have synthesised *cyclohexane-1-benzoyl-1-acetic acid* (IV, X=COPh ; R=H) from the acid chloride of the acid-ester of (IV, X=COOH ; R=H) and benzene by Friedel-Craft's reaction. The configuration of the acid (IV, X=COPh ; R=H) has been decided from the fact that it gives the benzylacetic acid (IV, X=CH<sub>2</sub>Ph ; R=H) on reduction and on hydrolysis it produces a well characterised ketonic acid which gives a semicarbazone without any difficulty.

*cyclohexane-1-benzoyl-1-acetic acid* also could not be converted into the lactonic compound or into the cyclol structure on being treated with acetic anhydride and potassium hydroxide respectively.

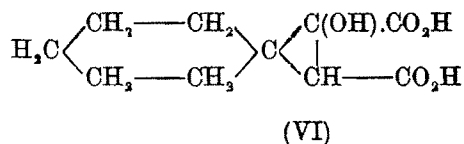
It was thought that perhaps by increasing the negative character of the phenyl residue still further, the tautomeric change in *cyclohexane-1-anisoyl-1-acetic acid* might be induced.

The synthesis of the anisoyl compound (IV, R=CO.C<sub>6</sub>H<sub>4</sub>OMe ; X=Me) has been very carefully effected. There is no doubt about its being a ketonic compound, as no difficulty is encountered in the formation of its semicarbazone or in its reduction to the anisyl compound (IV, R=CH<sub>2</sub>.C<sub>6</sub>H<sub>4</sub>OMe ; X=H). But this compound also shows no tendency to give a cyclol or a lactol derivative as is expected.

We therefore felt it necessary to repeat the work of Lanfear and Thorpe (*loc cit.*) and to see if the keto-acid (IV, X=CO.CO<sub>2</sub>H ; R=H) actually exhibited any tendency to its conversion into the cyclol acid (VI) as has been claimed by earlier workers and on which observation the important theory of valency deflexion by substituents has grown up. For the synthesis of the ketonic acid (IV, X=CO.CO<sub>2</sub>H ; X=H), we selected the method of Bardhan, employed in the synthesis of Balbiano's acid (*J. Chem. Soc.*, 1928, 2591, 2604), *cyclohexane-1-acetyl-1-acetic acid* on oxidation with potassium permanganate gives the keto-glutaric acid (IV, X=CO.CO<sub>2</sub>H ; R=H), m p. 130°. The identity of this acid with that of Lanfear and Thorpe has been established by its preparation by the method described by them and thereafter their direct comparison.



We are very much surprised to find that even after repeated treatment of the *cyclohexane-1-oxalyl-1-acetic acid* with a concentrated solution of potassium hydroxide, as suggested by Lanfear and Thorpe, the original ketonic acid is recovered, practically quantitatively unchanged. The experiment was repeated.



The conclusions regarding keto-cyclol tautomeric change of Thorpe and his collaborators must therefore be accepted with some reserve. It is expected that further work in this direction will give us more definite idea about the valency deflection hypothesis in its application to keto-cyclol tautomeric change.

#### EXPERIMENTAL

*Methyl cyclohexane-1-carboxy-1-acetate* was prepared by boiling the anhydride of *cyclohexane-1-carboxy-1-acetic acid* (46 g.) with methyl alcohol (28 c.c.) for 5 hours under a reflux. The half ester was isolated in the usual way after removing the excess of methyl alcohol as completely as possible. The heavy oil that was then isolated was left in a vacuum desiccator for about 48 hours, when it set to a solid crystalline mass. A portion of it was crystallised from petroleum ether (b.p. 40-50°) when it melted at 57°. (Found: C, 59.89; H, 7.88.  $\text{C}_{10}\text{H}_{18}\text{O}_3$  requires C, 60.0; H, 8.0 per cent).

*Methyl cycloHexane-1-acetyl-1-acetate*.—For the preparation of this compound, the half ester of *cyclohexane-1-carboxy-1-acetic acid* (20 g.) was warmed with thionyl chloride (13 c.c.) at 45-48° for 1½ hours. The excess of thionyl chloride was removed at 50° under reduced pressure. The acid chloride thus obtained was diluted with anhydrous benzene (25 c.c.) and added to a cooled solution of zinc methyl iodide, prepared from methyl iodide (20.8 c.c.), ethyl acetate (10.8 c.c.), sodium-dried benzene (25 c.c.) and zinc-copper couple (43 g.). The reaction mixture was worked up in the usual way when methyl keto-ester was obtained as a mobile liquid with a characteristic smell boiling at 122°/8 mm., yield 14 g. On redistillation it boiled at 120°/7 mm. (Found: C, 66.54; H, 8.78.  $\text{C}_{11}\text{H}_{18}\text{O}_3$  requires C, 66.66; H, 9.04 per cent). The keto-ester gave a *semicarbazone* very readily when crystallised from dilute methyl alcohol, m.p. 148°. (Found: C, 56.78; H, 7.99.  $\text{C}_{12}\text{H}_{21}\text{O}_3\text{N}$  requires C, 56.47; H, 8.23 per cent).

*Ethyl cyclohexane-1-acetyl-1-acetate* was prepared precisely in the same way as the methyl ester, only with this difference that ethyl *cyclohexane-1-carboxy-1-acetate* was a liquid. The keto-ester boiled at 137-138°/7mm. Rothstein and Thorpe (*loc. cit.*) gave a *semicarbazone*, m.p. 111°. (Found: C, 58.12; H, 8.12.  $\text{C}_{13}\text{H}_{23}\text{O}_3\text{N}$  requires C, 57.99; H, 8.54 per cent).

*cycloHexane-1-acetyl-1-acetic acid* was prepared from the methyl ester (20 g.), potassium hydroxide (20 g.) in water (20 c.c.) and rectified spirit (250 c.c.). The

acid was isolated in the usual way as a crystalline solid from benzene and light petroleum, m. p.  $82^{\circ}$  (cf. Rothstein and Thorpe, *loc. cit.*). [Found : M. W. (titration), 184.2.  $C_{10}H_{16}O_2$ , requires M. W., 184].

The acid was esterified by Phelps and Tillotson's method when it gave the normal ethyl ester, just described, giving the same semicarbazone, m. p.  $111^{\circ}$ .

The above acid (1 g.) was mixed with acetyl chloride (10 c. c.) and refluxed on the water-bath for  $\frac{1}{2}$  hour, excess of acetyl chloride was distilled off and the residue was treated with water and sodium carbonate solution when 0.8 g. of the original acid was recovered unchanged. When acetic anhydride was substituted for acetyl chloride and the mixture was heated for  $\frac{1}{2}$  hour, the original acid was recovered unchanged. The acid (2 g.) on being boiled with concentrated hydrochloric acid underwent no change; 1.8 g. were recovered. When 2 g. of the acid were heated with 64 g. of potassium hydroxide in 36 c. c. of water for 3 hours, 1.8 g. of the acid were isolated unchanged from the mixture. All these experiments show that the acid has no capacity to undergo a tautomeric change.

1-Ethyl cyclohexane-1-acetic acid was obtained by the reduction of cyclohexane-1-acetyl-1-acetic acid (3 g.), mixed with amalgamated zinc (15 g.) prepared by leaving it in contact with a solution of mercuric chloride (25 g.) in water (100 c. c.) for 1 hour. The mixture of the acid and zinc was heated under reflux with concentrated hydrochloric acid (15 c. c.) for 17 hours. The solution was then cooled well and extracted with ether. The ethereal solution was washed with a solution of sodium carbonate and the alkaline washing on acidification precipitated the acid, which was purified in the usual way when 1.5 g. of it were obtained. It crystallised from a mixture of benzene and petroleum, m. p.  $123^{\circ}$ . [Found : C, 70.39; H, 10.48; M., W. (by titration), 170.4.  $C_{10}H_{16}O_2$ , requires C, 70.58; H, 10.58 per cent. M. W., 170].

Methyl cyclohexane-1-benzoyl-1-acetate was prepared by converting the methyl cyclohexane-1-carboxy-1-acetate (15 g.) into the acid chloride by heating it with thionyl chloride (10 c. c.) at  $45-48^{\circ}$  for  $1\frac{1}{2}$  hours. Excess of thionyl chloride was distilled off under reduced pressure at about  $50^{\circ}$  and the acid chloride was mixed up with benzene (35 c. c.), dried over sodium. This mixture was efficiently cooled and finely powdered aluminium chloride (16.5 g.) was added in small quantities at a time. The mixture was allowed to stand overnight and the next day it was heated at  $65-70^{\circ}$  for about 3 hours. This was then decomposed with ice and dilute hydrochloric acid. Excess of benzene was then expelled by distillation in a current of steam and the residual heavy oil was extracted with ether. This was purified in the usual way when it solidified to a crystalline mass, yield 12.5 g. It was recrystallised from dilute alcohol, m. p.  $64^{\circ}$ . (Found : C, 73.04; H, 7.48.  $C_{16}H_{22}O_3$ , requires C, 73.84; H, 7.69 per cent). This keto-ester did not readily give a semicarbazone but on being refluxed on the water-bath for several hours with semicarbazide hydrochloride and sodium acetate in methyl alcoholic solution and on being left over for about 12 hours, a semicarbazone was isolated, which crystallised from aqueous methyl alcohol, m. p.  $155^{\circ}$ . (Found : C, 64.61; H, 7.22.  $C_{17}H_{23}O_3N_2$ , requires C, 64.35; H, 7.25 per cent).

cycloHexane-1-benzoyl-1-acetic acid was obtained by mixing the ester (7.5 g.) and

potassium hydroxide (7.5 g.) in water (7.5 c.c.) together and diluting the same with 200 c. c. of rectified spirit when a clear solution was obtained. The mixture was refluxed on the water-bath for 7 hours. Excess of alcohol was then distilled off and the residue was diluted with water (70 c. c.). This was extracted with ether and the alkaline solution was then acidified with hydrochloric acid and the solution was saturated with ammonium sulphate. The acid was then extracted with ether and isolated as usual. The oily residue solidified, yield 6.5 g. It crystallised from dilute acetic acid, m. p. 118°. [Found : C, 73.17; H, 7.26; M. W. (by titration), 246.3.  $C_{15}H_{18}O_3$  requires C, 73.13; H, 7.31 per cent. M.W., 246] It gave a *semicarbazone*, m. p. 133°. (Found : C, 63.54; H, 6.52.  $C_{16}H_{21}O_3N_3$  requires C, 63.36; H, 6.93 per cent). The acid showed no tendency to tautomerise under the ordinary conditions.

The acid (3 g.) was heated with amalgamated zinc (15 g.) and hydrochloric acid (15 c. c.) for 22 hours. The product was isolated as usual when it separated as a heavy oil, which solidified in a vacuum desiccator. *cycloHexane-1-benzyl-1-acetic acid* crystallises from acetic acid, m.p. 92°. [Found : C, 77.67; H, 8.43; M. W. (by titration), 232.  $C_{15}H_{20}O_2$  requires C, 77.58; H, 8.62 per cent. M. W., 232].

*Methyl cyclohexane-1-anisoyl-1-acetate* was prepared from the acid chloride of methyl *cyclohexane-1-acetate-1-acetic acid* (25 g.) which reacted with anisole (16 g.) in dry carbon disulphide (100 c.c.) in presence of finely powdered anhydrous aluminium chloride (30 g.). The temperature was kept low for over 18 hours and then it was heated to about 65-70° for 2 hours. This was then cooled and decomposed with crushed ice and hydrochloric acid. Excess of anisole and carbon disulphide were removed in a current of steam and the residue was extracted with ether. The residue on purification gave a solid (20 g.) which crystallised from dilute alcohol, m. p. 86°. (Found : C, 70.21; H, 7.5.  $C_{17}H_{22}O_4$  requires C, 70.34; H, 7.58 per cent).

This ester (15 g.) was hydrolysed with potassium hydroxide (15 g.) in 15 c.c. of water and 200 c.c. of spirit by heating for 8 hours. The alcohol was then removed under reduced pressure and the solution diluted and extracted with ether. The alkaline solution on acidification precipitated heavy oil which when purified solidified and crystallised from dilute acetic acid. This acid, *cyclohexane-1-anisoyl-1-acetic acid* melts at 126-27°. [Found : C, 69.61; H, 7.22; M. W. (by titration), 276.4.  $C_{16}H_{20}O_4$  requires C, 69.56; H, 7.24 per cent. M. W., 276]. The acid remains unaffected by the usual reagents for lactol or cyclol formation. The acid (10 g.) was reduced by 60 g. of amalgamated zinc and hydrochloric acid (40 c.c.) in course of 25 hours. *cycloHexane-1-p-methoxybenzoyl-1-acetic acid* was obtained as a crystalline solid, which crystallised from dilute alcohol and melted at 81-82°. [Found : C, 73.32; H, 8.4; M. W. (by titration), 262.2.  $C_{18}H_{22}O_5$  requires C, 73.28; H, 8.39 per cent M.W., 262].

*cycloHexane-1-oxalyl-1-acetic Acid*.—To a mixture of *cyclohexane-1-acetyl-1-acetic acid* (6.1 g.), potassium hydroxide (2 g.) and water (200 c.c.) was added a solution of potassium permanganate (12 g.) and potassium hydroxide (4 g.) in water (300 c.c.). The mixture was kept in ice-cold water for several hours and then at the ordinary temperature for 3 days, when it assumed a greenish tinge. This colour was discharged

with a few c.c. of rectified spirit and precipitated manganese dioxide was filtered off and extracted several times with hot water and then combined aqueous filtrate was concentrated, cooled and acidified with hydrochloric acid and it was extracted several times with ether. The ethereal layer on drying and removal of the solvent gave a crystalline solid mass (4.8 g.) This was crystallised several times from a mixture of chloroform and petroleum, m. p.  $130^{\circ}$ . [Found : C, 56.10 ; H, 6.44 ; M. W. (by titration), 214.4.  $C_{10}H_{14}O_3$  requires C, 56.04 ; H, 6.49 per cent. M. W., 214]. The acid gave a quinoxaline derivative which crystallised from methyl alcohol, m. p.  $246^{\circ}$ . (Found : C, 67.22 ; H, 6.18 ; N, 9.92.  $C_{10}H_{13}O_3N_2$  requires C, 67.13 ; H, 6.29 ; N, 9.79 per cent). (Lanfear and Thorpe, *loc. cit.*).

This keto-acid on reduction yielded *cyclohexane-1:1-diacetic acid* which was found to be identical with the acid prepared otherwise.

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# MOLECULAR STRUCTURE AND GRAY AND CRUICKSHANK'S METHOD OF CALCULATING MOLECULAR DIAMAGNETISM. PART I. UREA AND SUBSTITUTED UREAS

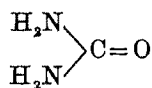
BY SUSHIL KUMAR SIDDHANTA

The magnetic susceptibility values for urea and substituted ureas have been calculated according to Gray and Cruickshank's method on the basis of evidence furnished by X-ray study of the crystal structure of urea. It has been shown that the calculated value differs considerably from the experimental one. The structures considered by Clow and his method of calculating the susceptibility value have been criticised and proved to be untenable, and the agreement obtained between the calculated and the experimental values by him has thus been shown to have little or no significance.

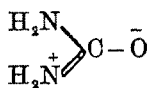
In a previous communication (Siddhanta and Ray, *J. Indian Chem. Soc.*, 1943, 20, 359), the values of molecular susceptibilities of dicyandiamide, acetamide and cyanuric acid were carefully determined and the values were compared with those calculated by the method of Gray and Cruickshank (*Trans. Faraday Soc.*, 1935, 31, 1491) using resonating structures established by X-ray analysis of the crystals of the compounds. It was shown that the agreement of the calculated values with the experimental ones was not close enough to justify the adoption of the aforesaid method as a reliable tool for exploring molecular structure.

Remarkable agreement between experimental  $\chi_M$  values and those calculated on the basis of the above-mentioned method has, however, been claimed by Gray and Cruickshank (*loc. cit.*) for benzene, naphthalene, carboxylic acids, water and hydrogen peroxide, and by Clow and co-workers (*Trans. Faraday Soc.*, 1937, 33, 381), for urea and its derivatives as well as for certain organic sulphur compounds besides several salts and esters of sulphates, sulphites, thiosulphates, etc. (*ibid.*, 1937, 33, 894; 1940, 36, 1018, 1029). From a consideration of the results set forth in the communication mentioned above (Siddhanta and Ray, *loc. cit.*), it is considered worthwhile to test the validity of these claims by a closer scrutiny of the evidences on which they are based.

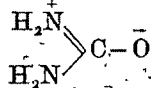
In this paper, it is proposed to deal with urea and substituted ureas studied by Clow (*loc. cit.*). From a consideration of the X-ray analysis of urea by Wyckoff and Corey (*Z. Krist.*, 1934, 89, 462), Pauling has shown that the substance resonates between three structures I, IIa, and IIb of which (I) contributes 60% and (IIa) and (IIb) contribute 20% each to the normal state of the molecule ("The Nature of Chemical Bonds", 1940, p. 212).



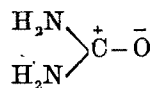
(I)



(IIa)



(IIb)

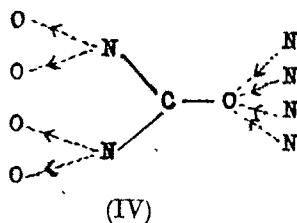


(III)

Viewed in the light of Gray and Cruickshank's method, structures (IIa) and (IIb) are identical. If the double bond is split up into a polarised single co-valent bond, as

suggested by Gray and Cruickshank, structure (III) would result from all the above cases. In Gray and Cruickshank's method of calculation, it is assumed that each double-bonded structure and the single co-valent structure, which arises from it by the splitting up of the double bond, contribute equally to the normal structure of the molecule; under these circumstances the resultant molecular susceptibility of the compound would be  $3/10$  due to (I),  $1/5$  due to (IIa and IIb) combined and  $\frac{1}{2}$  due to III (case A). If, however, we ignore the structure (III), the resultant molecular susceptibility will be  $3/5$  due to (I) and  $2/5$  due to IIa and to IIb combined (case B).

Structure IV shows the disposition of the H-bonds in the crystal of urea as shown by X-ray analysis. The direction of the arrow shows that the O atoms accept the H-bonds formed by the H atoms of the  $\text{-NH}_2$  groups in urea. Each oxygen atom receives four H-bonds and all the H atoms in urea molecule are engaged in bond-formation. It may, however, be pointed out that in Gray and Cruickshank's method of calculation, the oxygen atom in structure (I), having only two lone-pairs of electrons, can receive, according to these authors, two H-bonds in maximum, and similarly the O atoms in structures



(II) and (III), having three lone-pairs, can receive not more than three H-bonds. Hence in calculating the molecular susceptibility for the hydrogen-bonded structure, it has not been possible to make the calculation on the basis of four H-bonds per molecule of urea as found by X-ray analysis; the calculations have consequently been made for structure (I) assuming the presence of two H-bonds per molecule and for structures (II) and (III) assuming three H-bonds per molecule (i.e., taking the maximum number of H-bonds possible, according to Gray and Cruickshank's method, for the structure concerned). Table I summarises the results of calculation for the individual structures as well as for the cases A and B, with and without H-bonds.

TABLE I\*

Exp.  $\chi_m$  for urea = 33.60 (Pascal, *Ann. chim.*, 1912, 25, 355), 33.40 (Deveto, *Rend. Atti. Naz. Acad. Lincei*, 1932, 15, 973), 33.66 (Clow, *loc. cit.*).

Average  $\chi_m$  value = 33.55.

Structure.	$\chi_m$ (Gray and without H-bonds.	Cruickshank) with H-bonds.	$\chi_m$ (Pascal).	Resonance contribution.
I	27.46	30.19	$\left. \begin{matrix} 20.21 + \\ 27.13 \end{matrix} \right\}^{**}$	
II	25.48	29.19		
III	36.95	39.16		
Case A	31.82	34.48	....	$3/10(\text{I}) + 1/5(\text{II}) + \frac{1}{2}(\text{III})$
Case B	26.67	29.80	....	$3/5(\text{I}) + 2/5(\text{II})$

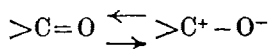
\*All the susceptibility values used in this paper are to be multiplied by  $-10^{-6}$

†The two N atoms diamidic and the O atom ordinary double-bonded.

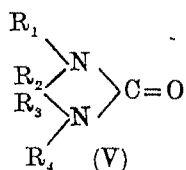
\*\*The two N atoms open chain and the O atom ordinary double-bonded

It may be noted that the calculated  $\chi_M$  value for none of the single or resonating structures, excepting case A with H-bonds, approaches the experimental value; the somewhat close approach of calculated  $\chi_M$  value for case A with H-bonds to the experimental value loses its significance because X-ray study has shown that case B with H-bonds should represent the actual state of the urea molecule.

Clow, however, is of opinion that since there is no molecule containing  $>C=O$  group in which the resonance

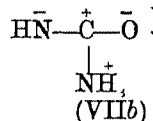
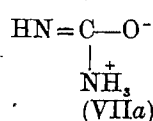
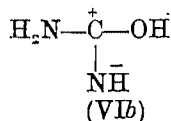
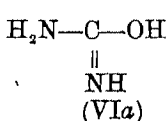


is prohibited, the calculation of diamagnetic susceptibility for such molecules already involves this resonance in the bond depression for  $>C=O$ ; hence, in the susceptibility calculation such resonance should not be considered.



On this view, Clow has assigned the non-resonating structure (V) to the tetra-substituted ureas, the calculated molecular susceptibilities for such structures being in agreement with the experimental values. But he rules out the carbamide structure (I) for ureas, as the calculated  $\chi_M$  value without considering the above type of resonance (*viz.*, between structures I and III) does not agree with the experimental value. The equal resonance of  $>C=O$  group between the double bonded structure and the single co-valent structure arising out of the splitting of the double bond, has, on the other hand, been particularly considered by Gray and Cruickshank themselves in the case of carboxylic acids (*loc cit.*) in order to obtain agreement between the experimental and the calculated  $\chi_M$  values. Thus we find that two contradictory hypotheses are necessary to obtain agreement between the experimental  $\chi_M$  value and that calculated by Gray and Cruickshank's method in the two cases discussed above.

Clow has also considered two other structures, (VI) and (VII), the amino-imino structure (VI) resonating equally between the forms (VIa) and (VIb), and the zwitterion structure VII (originally suggested by Werner) resonating equally between the forms (VIIa) and (VIIb). Table II shows the calculated  $\chi_M$  values for the different structures of urea considered by Clow. Since the mean  $\chi_M$  calculated for the zwitterion structure (VII) is in agreement with the experimental value, this structure for urea has



been accepted by Clow. It may be remarked that such a structure of urea can be definitely ruled out from the results of X-ray analysis; moreover, in calculating the  $\chi_M$  values, Clow has not considered the effect due to H-bonds which are most certainly present in the urea crystal. Furthermore, equal contribution to the normal state of the molecule by structures (VIIa) and (VIIb), even in such a molecule cannot be justified, as the structure (VIIb) must be unstable due to its having smaller number of co-valent bonds and to the juxtaposition of positive charges.

TABLE II

Structure.	Form a.	Form b.	Mean.
I	27.46	—	27.46
VI	25.75	37.63	31.69
VII	27.90	38.80	33.35

The amino-imino structure (VI) for urea might as well be made to account for the experimental  $\chi_m$  value on the assumption of 34% contribution by (VIa) and 66% by (VIb) to the normal state of the molecule. The postulate of equal resonance in every case between the double-bonded structure and the single-bonded structure resulting from the splitting of the double bond seems to be *ad hoc* and unjustified, and in this particular case of urea, in fact, has no realistic basis.

Clow has calculated the  $\chi_m$  value of mono-, di- and tri-substituted ureas for different structures (non-resonating carbamide, resonating amino-imino- and resonating zwitterion) by Gray and Cruickshank's method and has compared the values with the experimental ones; this has led to the conclusion that the resonating zwitterion structure of urea undergoes gradual transition to the non-resonating carbamide structure of tetra-substituted ureas through the amino-imino structures in mono-, di-, and tri-substituted ureas. The method of calculation employed by Clow in these cases also involves all the arbitrariness already pointed out in the case of urea; hence the agreement of the experimental  $\chi_m$  values with the calculated ones, in these cases as well, cannot be taken as an evidence of the reliability of Gray and Cruickshank's method as applied to resonating structures. The transition from zwitterion structure of urea to the carbamide structure through the amino-imino structure due to progressive substitution of H atoms in urea by heavier groups has little structural evidences except the enforced agreement of the diamagnetic susceptibility values. As has already been mentioned, the structure of urea itself in the solid state, has been found to differ entirely from that assigned by Clow.

Nevertheless, it cannot be denied that Gray and Cruickshank's method in the cases of resonating molecules like these, as has been pointed out by Siddhanta and Rây (*loc. cit.*), shows a decided improvement upon Pascal's method, though it fails to reproduce the experimental value within a limit to justify its adoption.

My grateful thanks are due to Prof. Priyadarajan Rây of the Calcutta University for his kind interest and guidance during the preparation of this paper. I also thank Dr. M. Ahmed, Principal, Rajshahi College, for the facilities to carry out the work.



# FAT FROM THE SEEDS OF *VANGUERA SPINOSA* (N.O. RUBIACEAE)\*

BY M. D. NADKARNI, J. W. AIRAN AND S. V. SHAH

The fat from the seeds of *Vanguera spinosa* contains an inseparable mixture of palmitic and stearic acids to the extent of 27.85% (the proportion of the two acids being 67.5% and 32.5 % respectively), oleic acid 32.46 % and linoleic acid 39.69 %.

The fact that the two solid acids could not be separated by the usual methods and I. V. accompanied by m. p. 50° are worth noting.

*Vanguera spinosa* (Marathi: Alu, Huloo; Hindi: Maina, Muduna) is distributed over North Bengal, Konkan, Deccan, Southern Maratha Country and North Kanare.. The fruit is smooth, globose, about one inch in diameter, yellowish when ripe and edible.

## EXPERIMENTAL

The seeds for this investigation were collected from a forest about 30 miles southwest of Kolhapur. The decorticated seeds were extracted with benzene in a Soxhlet, and the yield (38.5%) was calculated on this basis. The last traces of the solvent were removed by distillation under vacuum, whereupon the fat set to a semi-solid mass, which on warming on a water-bath, became thinner and transparent. The physical and chemical constants of this fat are given below.

TABLE I

Specific gravity		Iodine value	.. 88.63
at 24°/26°	.. 0.9515	Reichert-Meissel value	.. 1.56
Refractive index at 26°	.. 1.4780	Polenske number	.. 0.48
Acid number	.. 3.9	Acetyl value	.. 5.8
Saponification value	.. 190.75	Unsaponifiable matter	.. 0.95 %

*Insoluble Mixed Fatty Acids.*—The fat was saponified with alcoholic potash, and the soap, after being washed with ether to remove the unsaponifiable matter, was decomposed with hydrochloric acid to liberate the fatty acids. The liberated acids were taken up with ether, washed free from the mineral acids and dried over anhydrous sodium sulphate. Later, the ether was distilled off when the mixed fatty acids were left. The constants of these mixed fatty acids are given in Table II.

TABLE II

Yield.	Iodine value.	Acid number.	Mean M. W.
87%	103.2	201.7	277.65

According to this iodine value for the mixed fatty acids, that for the oil would be 89.32, which corresponds very well with the one actually found, namely 88.63.

The separation of the saturated and unsaturated fatty acids was effected by Twitshell's lead-salt method (*Ind. Eng. Chem.*, 1921, 13, 806).

\* A note on this subject appeared previously (*Current Sci.*, 1942, 11, 400).

Mixed acids taken	.. 39.34 g.
Solid acids obtained	.. 10.96 g. (27.86%)
Liquid acids obtained	.. 28.38 g. (72.14%)

*Solid Fatty Acids.*—The lead-salts of the saturated acids were decomposed with dilute nitric acid, and the liberated solid fatty acids were taken up with ether. The ether extract was washed with water till the washings were no longer acid to methyl orange. On the removal of the ether, the solid acids obtained gave the following values.

TABLE III

Iodine value	.. 3.49	Mean molecular weight	.. 267.6
Acid number	.. 209.3	Melting point (crude)	.. 52°

These crude solid acids (1.013 g.) on crystallisation from acetone gave the following fractions :

Fraction.	Wt.	M. p.	Fraction.	Wt.	M. p.
I	0.0884 g.	54-56°	V	0.0604 g.	54°
II	0.35	54-55°	VI	0.2672	54°
III	0.1174	54°	VII	0.056	54°
IV	0.0324	54°			

Excepting the first two fractions, the rest of them appear to be similar. Their mixed melting points with myristic, palmitic and stearic acids are given below :

With	Mixed melting point.
Myristic acid	47°
Palmitic acid	56°
Stearic acid	62°

This, and the fact that these solid acids have the mean molecular weight of 267-268 (as against 228 of myristic acid) rule out the possibility of fractions III to VII being exclusively those of myristic acid.

Another possibility is that, they may be identical with the so-called daturic acid ( $C_{17}H_{34}O_2$ ), which is reported to have melting points varying from 54° to 59° and a mean molecular weight of 270 (Giraud, *J. Soc. Chem. Ind.*, 1890, 9, 1137). Its identity as an individual acid was first reported by Meyer and Beer (*Monatsh.*, 1910, 31, 1239) by isolating it from Datura oil itself. It was, however, later found to be an equimolecular mixture of palmitic and stearic acids (Verkade and Coops, *Biochem. Z.*, 1929, 206, 468; Manjunath and Siddappa, *J. Indian Chem. Soc.*, 1935, 12, 400). Zinc salt of this acid was found by Meyer and Beer (*loc. cit.*) to melt at 126.6° (benzene).

Zinc salt of the saturated fatty acids obtained in the present investigation was sparingly soluble in boiling benzene and the crystallised salt melted at 119-20°. Katti and Puntambekar (*J. Indian Chem. Soc.*, 1930, 7, 225) reported a similar salt with m.p. 119-20°, obtained from a fraction of saturated acids from the seeds of *Caesalpinia Bonducella*.

Methyl esters of these mixed solid acids were prepared and then distilled under 15-20 mm. pressure. All the quantity came over between 180° and 183°. These gave the values noted in Table IV.

TABLE IV

Solidifying point	.. 25-26°
Saponification value	198.5
Mean molecular weight	.. 282.1

TABLE V

Acid number	.. 211.05
Mean molecular weight	.. 265.4
Melting point	.. 54-55°

From these esters original acids were recovered which gave values shown in Table V.

These figures (Table V) are similar to those obtained for the original acids, *i.e.* M. W. 267.6, and m.p. 54°.

Next, potassium salts of the mixed acids were prepared and crystallised from acetone. The various fractions were collected and the acids recovered from these fractions separately were found to have 54° as their melting point.

About 0.5 g. of the acids was dissolved in boiling alcohol and to this was added a boiling alcoholic solution of magnesium acetate, containing just enough salt to precipitate half the amount of the acid into its salt. The melting points of the acids recovered from the precipitated salt and of those from the filtrate did not vary, it being 54-55° in both the cases.

Such mixtures have been reported by many workers. Verkade and Coops (*loc. cit.*) subjected the methyl esters of the solid acids from the oil of *Datura stramonium* (the so-called daturic acid) to fractional distillation in vacuum and from a comparative study of the melting points of acids obtained from various fractions, with those of the acids from artificial mixtures of the methyl esters of stearic and palmitic acids, they concluded that the "daturic acid" was really a mixture of stearic and palmitic acids. Manjunath and Siddappa (*loc. cit.*) by intensive fractionation of the methyl esters of these acids found that they consisted of palmitic and stearic acids. Katti and Manjunath (*J. Indian Chem. Soc.*, 1929, 6, 842) also obtained a similar acid in lower fractions of the saturated fatty acids from the oil from the seeds of *Butea frondosa*. Further, Puntambekar and Katti (*loc. cit.*) obtained, together with palmitic and stearic acids, a similar acid (M. W. 270-272; m.p. 55-56°) in the intermediate fractions. The saturated acids, obtained during the present investigation, appear in all probability to be a mixture of palmitic and stearic acids of a similar type.

The percentage composition of this mixture, calculated on the basis of its molecular weight (265.4) works out to be 67.86% palmitic and 32.14% stearic acids. A mixture of the two acids melting at 54.5° has been reported by Hehner and Mitchell to consist of 67.5% palmitic and 32.5% stearic acids (Lewkowitsch, "Laboratory Companion to Oils and Fats Industry," p. 94). These values correspond well with the values obtained above. To confirm this further (assuming a mixture of 70 % palmitic and 30 % stearic acids) to the solid acids obtained, a known amount of pure stearic acid was added so as to make it a mixture with definite proportions as follows, and the melting points of different mixtures noted (Table VI),

TABLE VI

Composition.	Melting point
I.. Original (assuming 70% palmitic and 30% stearic)	54°
II. 50% palmitic and 50% stearic (by adding 0.08 g. stearic acid to 0.2 g. mixture)	57°-58°
III. 20% palmitic and 80% stearic (by adding 0.25 g. stearic acid to 0.1 g. mixture)	63°-64°

These melting points agree well with the values given by Hehner and Mitchell (*loc. cit.*).

Attempts were then made to prepare artificially such an inseparable mixture of the two acids by mixing 3.643 g. of pure palmitic acid with 1.607 g. of pure stearic acid. The mixture was kept in a sealed tube and melted by placing the tube in a hot water-bath. The contents of the tube were then shaken vigorously and left for a couple of days. A portion of this mixture was fractionally crystallised from pure acetone. The first fraction on further crystallisations gave pure stearic acid (m.p. 69°) and the last one yielded pure palmitic acid (m.p. 62°). About 1g. of the mixture was converted separately into its calcium, barium, and lead salts in the usual manner and the acids were recovered from the salts. The two component acids could be separated from these by fractional crystallisation from acetone.

Methyl esters of pure palmitic and stearic acids were next prepared separately and the two were mixed in calculated amounts so as to give ultimately a mixture of the two acids in desired proportion (70.30). Thus 7.384 g. of palmitic acid ester were mixed with 3.148 g. of stearic acid ester to form a complete homogeneous mixture and sealed in a tube. This tube was placed in a hot water-bath and was shaken vigorously and kept overnight. The mixture was then distilled fractionally under reduced pressure. The esters came over in four fractions between 220° and 234°. The fractions were saponified and the fatty acids liberated in the usual manner and were fractionally crystallised from acetone. The later fractions from the first two gave a melting point of 62° and their mixed melting point with an authentic sample of palmitic acid remained unchanged. The first fraction from the last lot had m. p. 65° which rose to 69° on further recrystallisation. No depression was noted in its mixed melting point with an authentic sample of stearic acid.

Similarly, an artificial mixture of ethyl esters of the two acids was prepared (4.646 g. of palmitic acid ester and 2.194 g. of stearic acid ester) and treated in exactly the same manner as the mixtures of methyl esters above. Finally the two acids could be separated in this case also.

Since stearic acid can be steam distilled without decomposition, a certain quantity of the total acids (solid) obtained from the fat under investigation, was steam-distilled. From the distillate was obtained a solid which melted at 60° (crude) and finally after recrystallisation gave a melting point of 65-66°. This was found identical with stearic acid by mixed m. p. Then a much small portion of the total solid acids was again steam-distilled for a long time; the residue, after repeated crystallisation gave an acid which was identical with palmitic acid (confirmed by mixed m. p.). Thus qualitatively the two component solid acids (stearic and palmitic) were separated from this very intimate mixture of the total solid acids.

*Unsaturated Fatty Acids.*—These acids were liberated from the liquid lead salts with dilute hydrochloric acid, and were taken up with ether. The ethereal solution of

these acids was washed free from hydrochloric acid and dried over anhydrous sodium sulphate overnight. Next day the ether was removed by distillation completely, and the acids thus obtained gave the following values.

TABLE VII

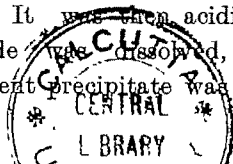
Iodine value	Acid number	Mean M. W.
145.4	197.85	283.05

According to this iodine value for the mixed liquid acids, that for the total mixed fatty acids would work out to 104.8, whereas the actual value is 103.2.

*Bromination of Liquid Acids.*—The acids (12.837 g.) were dissolved in 50 c.c. glacial acetic acid. Bromine was dissolved separately in an equal volume of glacial acetic acid, and the two were kept in an ice-box for a while. The bromine solution was then added to the acid solution gradually with constant stirring till the colour of bromine persisted. Except for shaking, the flask was kept in ice all along. The reaction mixture was left in the ice-box overnight, when a white crystalline solid separated. The solution was filtered, and the solid left behind was washed and recrystallised from alcohol. The filtrate was poured into water and washed free from the acetic acid. The residual mass was rubbed with petroleum ether for a long time, but no further solid compound separated out. The petroleum ether solution was then washed with a dilute solution of sodium thiosulphate to remove free bromine, if any, and then it was dried thoroughly. The petroleum ether was then distilled off, when the liquid bromo derivative was obtained. The bromine in both these derivatives was estimated. The solid bromo derivative (m. p. 112-13°) contained 52.16% and the liquid bromo derivative, 35.22% bromine. The former corresponds to linoleic tetrabromide m. p. 114° (Br, 53.33%) and the latter to oleic dibromide (Br, 36.18%).

The unsaturated acids (12.837 g.) gave 15.18 g. of linoleic tetrabromide, and 9.051 g. of oleic dibromide. These quantities correspond respectively to 7.063 g. linoleic acid, and 5.774 g. oleic acid. Thus their percentages are 55 and 45 respectively. On this basis, the iodine value of the mixed liquid acids and that for the total mixed fatty acids work out to 142.62 and 102.7 respectively, whereas those actually obtained are 145.4 and 103.2. The mixed melting point of linoleic tetrabromide obtained with an authentic sample of the same was 112-13°.

*Oxidation of Liquid Acids.*—A portion of the mixed liquid acids was oxidised with potassium permanganate in an alkaline solution by the method of Hazura (Lewkowitsch, "Chemical Technology and Analysis of Oils, Fats, and Waxes," Edn VI, Vol. I, p. 575). The acids were saponified with alcoholic potash and the soaps formed were dissolved in water after distilling off the alcohol. To this solution was added about 1.5 % cold potassium permanganate solution in a thin stream with constant stirring, till the lather formed at the top showed a pink tinge. The solution was then allowed to stand overnight. It was then acidified with sulphurous acid till all the hydrated manganese peroxide was dissolved, and the solution became colourless and acidic. A white flocculent precipitate was obtained.



The precipitated acids were first washed with water and then with petroleum ether to remove the unoxidised acids, if any. They were then extracted with a large amount of ether and filtered. The filtrate gave a white solid, m. p. 127-28°. This, on recrystallisation from alcohol, melted at 130-31°. It was dihydroxystearic acid.

The residue, insoluble in ether, was dissolved in hot alcohol and crystallised, when a white solid (m.p. 157-58°) was obtained. This is probably the tetrahydroxystearic acid which is reported to exist in various isomeric forms and whose melting points vary between 155° and 180° (Katti and Puntambekar, *loc. cit.* Krishna and Puntambekar, *J. Indian Chem. Soc.*, 1931, 8, 304). No acid was detected in the filtrate after the removal of the above two acids. This confirms that only oleic and linoleic acids are present in the unsaturated acids.

Thus the percentages of the fatty acids contained in the fat are : palmitic and stearic acids (forming a very intimate mixture), 27.85 ; oleic acid, 32.46 ; linoleic acid, 39.69.

*Unsaponifiable Matter.*—The ethereal washings of the potassium soaps of the fat were washed with water completely. The ether was then evaporated when a white solid was obtained. This was crystallised from hot alcohol. The solid that separated on cooling was wax-like and melted at 56-58°. It was insoluble in concentrated sulphuric acid. It may be a saturated hydrocarbon.

The filtrate later gave a white substance, m.p. 205-210°. On viewing through a microscope, needle shaped crystals were observed. It dissolved in cold concentrated sulphuric acid, giving the solution a pink colour, thereby indicating that it was a sterol. Its acetate melted at 62-63°.

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## STUDIES IN SULPHANILAMIDES. PART X. SOME N<sup>1</sup>- AND N<sup>4</sup>-ALKYLENE BIS-SULPHANILAMIDES\*

BY HARKRISHAN LAL BAMI, BALKRISHNA HARIHAR IYER AND PRAPHULLA CHANDRA GUHA

Sulphanilamide and potassium salt of acetylsulphanilamide have been condensed with various alkylene dibromides to give N<sup>4</sup>- and N<sup>1</sup>- alkylene *bis*-sulphanilamides, respectively.

Trefouel *et al.* (*Ann. Inst. Pasteur*, 1937, 58, 30) found N<sup>1</sup>-alkyl and N<sup>1</sup>-dialkyl derivatives of sulphanilamide to be active against experimental streptococcal infection. Buttle, Grey and Stephenson (*Biochem. J.*, 1937, 31, 724) have, however, reported that N<sup>1</sup>-diethylsulphanilamide is more toxic than sulphanilamide. Crossley *et al.* (*J. Amer. Chem. Soc.*, 1938, 60, 2222) have reported that some alkyl disulphanilamides are better than sulphanilamide against  $\beta$ -hemolytic streptococcal infection in mice. Man and Watson (*J. Chem. Soc.*, 1943, 606) also prepared some simple poly-sulphanilamides in order to test their activity against malarial infection.

With a view to preparing sulpha-derivatives having sulphanilamide molecule linked at either end of an alkylene chain of varying length at N<sup>4</sup> and N<sup>1</sup> position, the action of various alkylene dibromides on sulphanilamide and potassium salt of N<sup>4</sup>-acetylaminobenzenesulphonamide has been studied. While the alkylene chain may reduce the solubility of the drug in common organic solvents, it may possibly render the molecule more fat-soluble. The two sulphanilamide residues in this case are expected to exert their potency as a general bacteriostatic agent.

Crossley *et al.* (*J. Amer. Chem. Soc.*, 1940, 62, 532) prepared 1:2-*bis*-sulphanilamidoethane (N<sup>1</sup>) by reacting *p*-acetaminobenzenesulphonyl chloride with ethylene-diamine, and Northey and Hulquist (U. S. patent No. 2258162) reported it to be therapeutically active. According to Walker (*J. Chem. Soc.*, 1940, 686), if any alkyl halide reacts with sulphanilamide, then N<sup>4</sup>- amino group is preferentially alkylated; however, with N<sup>4</sup>-acetylsulphanilamide, alkylation takes place entirely at N<sup>1</sup>-position. Preparation of potassium salt of N<sup>4</sup>-acetylsulphanilamide makes it still more suitable for reaction.

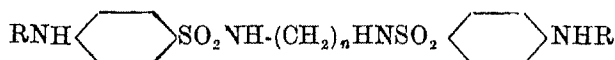
Various alkylene dibromides chosen for the present work are methylene, ethylene, tri, tetra- and penta-methylene dibromides.

When the potassium salt of N<sup>4</sup>-acetylsulphanilamide is reacted with the different alkylene dihalides and the resulting acetyl derivatives hydrolysed, alkylene-*bis*-N<sup>1</sup>-sulphanilamides of type (A) (II), (IV), (V), (VI), and (VII) result. While the acetyl derivatives (I) and (III) corresponding to (II) and (IV) respectively have been obtained in a pure state, those corresponding to (V), (VI) and (VII) could not be isolated in a pure state.

By the action of various alkylene dibromides on sulphanilamide, the alkylene-*bis*-N<sup>4</sup>-sulphanilamides (VIII), (IX), (X), (XI) and (XII) of type (B) are obtained.

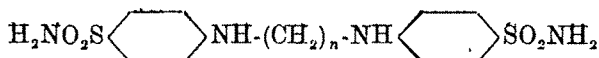
\* A preliminary note of this work was published in *Science & Culture*, 1945, 11, 269.

## TYPE A



- |                                |       |              |       |
|--------------------------------|-------|--------------|-------|
| (I) R = -COCH <sub>3</sub> ;   | n = 1 | (V) R = H;   | n = 3 |
| (II) R = H;                    | n = 1 | (VI) R = H;  | n = 4 |
| (III) R = -COCH <sub>3</sub> ; | n = 2 | (VII) R = H; | n = 5 |
| (IV) R = H;                    | n = 2 |              |       |

## TYPE B



- (VIII)  $n=1$ ; (IX)  $n=2$ ; (X)  $n=3$ ; (XI)  $n=4$ ; (XII)  $n=5$ .

## EXPERIMENTAL

*Methylene-bis-N<sup>1</sup>-(N<sup>4</sup>-acetylsulphanilamide)* (I).—Dry powdered potassium salt of acetylsulphanilamide (10 g.) and methylene dibromide (10 c.c.) were taken in a soda water bottle and heated under pressure in an oil-bath at 120-130° for 6 hours. The excess of methylene dibromide was steam-distilled and the product obtained, was filtered hot after boiling with water (40 c.c.). It was not possible to crystallise it from common organic solvents and hence it was purified by precipitation with acid from its dilute alkali solution, filtered, washed well with water and alcohol and dried as white amorphous powder, m. p. 210°, yield 7.8 g. (Found: N, 13.07; S, 14.5. C<sub>17</sub>H<sub>20</sub>O<sub>6</sub>N<sub>4</sub>S<sub>2</sub> requires N, 12.72; S, 14.47 per cent).

*Methylene-bis-N<sup>1</sup>-(sulphanilamide)* (II).—Methylene-bis-N<sup>1</sup>-(N<sup>4</sup>-acetylsulphanilamide) (4 g.) was refluxed for 1½ hours with hydrochloric acid (15%, 30 c.c.). The solution was filtered and the product obtained on neutralisation with alkali. It was collected by filtration, washed with water and alcohol and dried as a light coloured, amorphous powder, m.p. 296° (decomp.), yield 2.3 g. (Found: N, 15.38; S, 17.56. C<sub>13</sub>H<sub>16</sub>O<sub>4</sub>N<sub>4</sub>S<sub>2</sub> requires N, 15.73; S, 17.97 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-acetylsulphanilamide)* (III).—Potassium salt of acetylsulphanilamide (10 g.) and ethylene dibromide (12 c.c.) were heated together under reflux in an oil-bath at 150-155° for 6 hours. The excess of ethylene dibromide was then steam-distilled and the residual solid was ground with hot water (20 c.c.) and filtered. The hot water-insoluble product was washed well with further quantities of hot water and the product dried in an air-oven. The product was found insoluble in the usual organic solvents. It was precipitated from its dilute alkali solution by acid, filtered, washed well with water and alcohol, and finally dried as a white amorphous powder, m. p. 275°, yield 8.1 g. (Found: N, 12.37; S, 14.2. C<sub>18</sub>H<sub>22</sub>O<sub>6</sub>N<sub>4</sub>S<sub>2</sub> requires N, 12.33; S, 14.03 per cent).

*Ethylene bis-N<sup>1</sup>-(sulphanilamide)* (IV) — Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-acetylsulphanilamide) (2.5 g.) was refluxed with hydrochloric acid (15%, 30 c.c.) for 2 hours. The solution



was filtered and neutralised with dilute alkali. The hydrolysed product came up as a white precipitate which was collected by filtration, washed well with water and alcohol, and dried. The product was insoluble in common organic solvents and hence could not be crystallised. The compound was purified by precipitation from its dilute alkali solution with acid after treating with charcoal (norit). The product was finally filtered, washed and dried as a white amorphous powder, m.p. 228°, yield, 1.5 g. (Found: N, 15.3; S, 17.4.  $C_{14}H_{18}O_4N_4S_2$  requires N, 15.14; S, 17.29 per cent).

*Trimethylene-bis-N<sup>1</sup>-sulphanilamide* (V).—Potassium salt of acetylsulphanilamide (10 g.) and trimethylene dibromide (10 c.c.) were refluxed for 6 hours at 150–160° in an oil-bath. When the excess trimethylene dibromide was removed by steam-distillation, a sticky product resulted. As this crude product could not be purified, it was directly hydrolysed with hydrochloric acid (15%, 40 c.c.) by refluxing for 2 hours. The pasty product, obtained on neutralising the filtrate with dilute alkali, was purified by twice precipitation from its dilute alkali solution by acid after having treated with norit. It was obtained as a white amorphous powder, m.p. 170°, yield 3 g. (Found: N, 14.8; S, 16.31.  $C_{15}H_{20}O_4N_4S_2$  requires N, 14.55; S, 16.66 per cent).

*Tetramethylene-bis-N<sup>1</sup>-(sulphanilamide)* (VI).—Potassium salt of acetylsulphanilamide (1.5 g.) and tetramethylene dibromide (3 c.c.) were refluxed for 4 hours at 150–160°. The starting materials were removed and the acetyl product directly hydrolysed as in (V). The crude product was purified by precipitation with acid from its dilute alkali solution after treating with norit and finally extracted with ether. The ether extract on evaporation gave a dry amorphous powder, m.p. 150°, yield 0.5 g. (Found: N, 13.7; S, 15.71.  $C_{16}H_{22}O_4N_4S_2$  requires N, 14.07; S 16.08 per cent).

*Pentamethylene-bis-N<sup>1</sup>-(sulphanilamide)* (VII).—Potassium salt of acetylsulphanilamide (2 g.) and pentamethylene dibromide (4 c.c.) were reacted together and the product isolated and purified as in (VI) as a white amorphous powder, m.p. 142°, yield 0.9 g. (Found: N, 13.2; S, 15.1.  $C_{17}H_{24}O_4N_4S_2$  requires N, 13.59; S, 15.53 per cent).

*Methylene-bis-N<sup>4</sup>-sulphanilamide* (VIII).—Sulphanilamide (6 g.) and methylene dibromide (10 c.c.) were reacted together under pressure as described in (I). The excess of methylene dibromide was steam-distilled and unreacted sulphanilamide removed by grinding the product with dilute hydrochloric acid. The product could not be crystallised from the usual organic solvents. The product was purified by precipitation from its alkali solution with acid after treating with norit as a white amorphous powder, m.p. 196°, yield 2.6 g. (Found: N, 15.4; S, 17.4.  $C_{13}H_{16}O_4N_4S_2$  requires N, 15.73; S, 17.97 per cent).

*Ethylene-bis-N<sup>4</sup>-sulphanilamide* (IX).—Sulphanilamide (10 g.) and ethylene dibromide (10 c.c.) were heated under reflux for 6 hours at 140–150° in an oil-bath. The starting materials were removed as described in (VIII). The acid-insoluble portion was insoluble in organic solvents and was crystallised twice from water as white silky needles, m.p. 204°, yield 3.5 g. (Found: N, 15.85; S, 16.85.  $C_{11}H_{14}O_4N_4S_2$  requires N, 15.15; S, 17.29 per cent).

*Trimethylene-bis-N<sup>4</sup>-sulphanilamide* (X).—Sulphanilamide (5 g.) and trimethylene dibromide (5 c.c.) were refluxed together for 5 hours at 160–170°. The excess halide was steam-distilled and the residual brown paste directly dissolved in dilute alkali.

The alkali solution was treated with charcoal (norit), filtered and acidified by excess dilute hydrochloric acid. The acid-insoluble product was removed and purified by precipitation as described in (V) as a white amorphous powder, m.p.  $180^{\circ}$ , yield 1.1 g. (Found : N, 14.13 ; S, 16.10.  $C_{15}H_{20}O_4N_4S_2$  requires N, 14.55 ; S, 16.66 per cent).

*Tetramethylene-bis-N<sup>4</sup>-sulphanilamide* (XI).—Sulphanilamide (2 g.) and tetramethylene dibromide (4 c.c.) were reacted together and the product obtained as in (X) as a white powder m.p.  $138^{\circ}$ , yield 1.1 g. (Found : N, 13.97 ; S, 15.5.  $C_{15}H_{22}O_4N_4S_2$  requires N, 14.07 ; S, 16.08 per cent).

*Pentamethylene-bis-N<sup>4</sup>-sulphanilamide* (XII).—Sulphanilamide (2 g.) and pentamethylene dibromide (3 c.c.) were reacted together and the product obtained as in (X) as a white powder, m.p.  $155^{\circ}$ , yield 1.2 g. (Found ; N, 13.5 ; S, 15.5.  $C_{17}H_{24}O_4N_4S_2$  requires N, 13.59 ; S, 15.53 per cent).

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# STUDIES IN SULPHANILAMIDES. PART XI. SOME AZO DYES OF ETHYLENE-BIS-N<sup>1</sup>-SULPHANILAMIDE\*

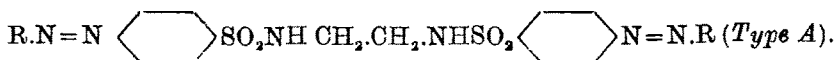
BY HARKRISHAN LAL BAMI, BALKRISHNA HARIHAR IYER AND  
PRAPHULLA CHANDRA GUHA

Aromatic amino-azo dyes and aromatic hydroxy-azo dyes of ethylene-bis-N<sup>1</sup>-sulphanilamide have been prepared by coupling tetrazotised ethylene-bis-N<sup>1</sup>-sulphanilamide with various aromatic hydroxy compounds and aromatic amines.

Gley and Girard (*Presse. Med.*, 1936, **42**, 1775 ; cf. Rajagopalan, *Proc. Indian Acad. Sci.*, 1944, **19A**, 351) made the interesting observation that inspite of the molecular amounts of prontosil and sulphanilamide being equal in activity against streptococcal infection, the carboxy derivatives of prontosil were twice as active although it could liberate no more sulphanilamide than the previous drug *in vivo*.

Considering the encouraging activity of azo dyes of sulpha-family, especially prontosil (Domagk, *Deut. Med. Wochschr.*, 1935, **61**, 250,) and rubiazol (Levaditi and Vaisman *Compt. rend.*, 1935, **200**, 1694) and those obtained from N<sup>1</sup>-alkylsulphanilamides (Lydia and Aldo, *Gazzetta*, 1940, **70**, 369) it was thought worthwhile to prepare some important azo derivatives of ethylene-bis-N<sup>1</sup>-sulphanilamide (Bami, Iyer and Guha, *Science & Culture*, 1945, **11**, 269).

Ethylene-bis-N<sup>1</sup>-sulphanilamide has been tetrazotised and coupled with two molecular proportions of various aromatic hydroxy compounds to give the azo dyes of type A from (I—X).



(R=coupling agent mentioned after each compound less one hydrogen)

- |                               |                                  |
|-------------------------------|----------------------------------|
| (I) R=phenol                  | (VI) R=resorcinol                |
| (II) R= <i>p</i> -cresol      | (VII) R=resorcinol ethyl ether   |
| (III) R=1:2:5-xylenol         | (VIII) R=resorcinol methyl ether |
| (IV) R= <i>o</i> -nitrophenol | (IX) R= $\alpha$ -naphthol       |
| (V) R=salicylic acid          | (X) R= $\beta$ -naphthol         |

The tetrazonium salt of ethylene-bis-sulphanilamide has been reacted with two molecular proportions of various aromatic amines to give the azo dyes of type A from (XI—XX).

- |                               |                                       |
|-------------------------------|---------------------------------------|
| (XI) R=aniline                | (XVI) R= <i>p</i> -anisidine          |
| (XII) R= <i>p</i> -toluidine  | (XVII) R=anthranilic acid             |
| (XIII) R=1:3:6-xyldine        | (XVIII) R= <i>m</i> -phenylenediamine |
| (XIV) R=dimethylaniline       | (XIX) R= $\beta$ -naphthylamine       |
| (XV) R= <i>m</i> -aminophenol | (XX) R=naphthionic acid               |

\* A preliminary note of this work has been published in *Science & culture* 1946, **12**, 153.

All these dyes are coloured, amorphous powders with shades varying from light red to dark brown. They cannot be crystallised and they usually decompose on melting.

## EXPERIMENTAL

*Ethylene-bis-N<sup>1</sup>-(4-hydroxybenzeneazophenyl-p-sulphonamide)* (I).— *Ethylene-bis-N<sup>1</sup>-sulphanilamide* (1 g.) was dissolved in sodium hydroxide solution (10%, 3 c.c.). The solution was cooled to 0° and sodium nitrite solution (10%, 4 c.c.) was added to it. Hydrochloric acid (10%, 5 c.c.) was then added drop by drop with stirring and the reaction mixture allowed to stand for half-an-hour when the diazonium salt was obtained as a light yellow precipitate.

The above mixture was added to phenol (0.6 g.), dissolved in sodium hydroxide solution (10%, 10 c.c.), cooled at 0°, when a red solution of the sodium salt of the dye was obtained. After 2 hours the dye was precipitated with dilute hydrochloric acid, filtered and washed well with cold water. The product could not be crystallised from usual organic solvents and hence it was purified from the dilute alkali solution by precipitation with acid after stirring with norit in cold. The product was filtered, washed and dried and obtained as a reddish amorphous powder, m.p. 175° (decomp.), yield 1.4 g. (Found: N, 13.91.  $C_{26}H_{24}O_6N_6S_2$  requires N, 14.52 per cent).

*Ethylene-bis-N<sup>1</sup>-(2-hydroxy 5-methylbenzeneazophenyl-p-sulphonamide)* (II).— *Ethylene-bis-N<sup>1</sup>-sulphanilamide* (1 g.) was tetrazotised and coupled with *p*-cresol (0.6 g.) in excess of sodium hydroxide at 0° as described under (I). Finally, a red powder was obtained, m.p. 150° (decomp.), yield 1.5 g. (Found: N, 13.73.  $C_{26}H_{28}O_6N_6S_2$  requires N, 13.81 per cent).

*Ethylene-bis-N<sup>1</sup>-(2:5-dimethyl-4-hydroxybenzeneazophenyl-p-sulphonamide)* (III). — *Ethylene-bis-N<sup>1</sup>-sulphanilamide* (1 g.) was tetrazotised and coupled with 1:2:5-xylenol (0.7 g.) as described under (I). The purified product was obtained as a red powder, m.p. 172° (decomp.), yield 1.6 g. (Found: N, 12.95.  $C_{30}H_{30}O_6N_6S_2$  requires N, 13.20 per cent).

*Ethylene-bis-N<sup>1</sup>-(3-nitro-4-hydroxybenzeneazophenyl-p-sulphonamide)* (IV).— *Ethylene-bis-N<sup>1</sup>-sulphanilamide* (1 g.) was tetrazotised and coupled with *o*-nitrophenol (0.8 g.) as described under (I). The product was obtained as a reddish yellow powder, m.p. 171° (decomp.), yield 1.6 g. (Found: N, 16.03.  $C_{26}H_{28}O_{10}N_8S_2$  requires N, 16.73 per cent).

*Ethylene-bis-N<sup>1</sup>-(4-hydroxy-5-carboxylic-benzeneazophenyl-p-sulphonamide)* (V).— *Ethylene-bis-N<sup>1</sup>-sulphanilamide* (1 g.) was tetrazotised and coupled with salicylic acid (0.8 g.) and the product obtained as under (I) as a light brown powder, m.p. 236° (decomp.), yield 1.6 g. (Found: N, 12.21.  $C_{28}H_{24}O_{10}N_6S_2$  requires N, 12.56 per cent).

*Ethylene-bis-N<sup>1</sup>-(2:4-dihydroxybenzeneazophenyl-p-sulphonamide)* (VI).— *Ethylene-bis-N<sup>1</sup>-sulphanilamide* (1 g.) was tetrazotised and coupled with resorcinol (0.6 g.) as under (I). Finally the product was obtained as a brown powder with no definite decomposition point, yield 1.5 g. (Found: N, 13.4.  $C_{26}N_{24}O_8N_6S_2$  requires N, 13.72 per cent).

*Ethylene-bis-N<sup>1</sup>-(2-ethoxy-4-hydroxybenzeneazophenyl-p-sulphonamide)* (VII).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1 g.) was tetrazotised and coupled with resorcinol monoethyl ether (0.8 g.) as under (I). The product was isolated and purified as before and obtained as a dark red powder, m.p. 145° (decomp.), yield 1.5 g. (Found: N, 12.1. C<sub>20</sub>H<sub>22</sub>O<sub>6</sub>N<sub>6</sub>S<sub>2</sub> requires N, 12.57 per cent).

*Ethylene-bis-N<sup>1</sup>-(2-methoxy-4-hydroxybenzeneazophenyl-p-sulphonamide)* (VIII).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1 g.) was tetrazotised and coupled with resorcinol monomethyl ether (0.7 g.) and the product obtained as a dark red dye, m.p. 192° (decomp.), yield 1.5 g. (Found: N, 13.58. C<sub>20</sub>H<sub>22</sub>O<sub>6</sub>N<sub>6</sub>S<sub>2</sub> requires N, 13.12 per cent).

*Ethylene-bis-N<sup>1</sup>-(1-hydroxynaphthylazophenyl-p-sulphonamide)* (IX).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1 g.) and  $\alpha$ -naphthol (0.8 g.) were coupled together and the product obtained as a brown powder, m.p. 152° (decomp.), yield 1.6 g. (Found: N, 11.99. C<sub>24</sub>H<sub>20</sub>O<sub>6</sub>N<sub>6</sub>S<sub>2</sub> requires N, 12.42 per cent).

*Ethylene-bis-N<sup>1</sup>-(2-hydroxynaphthyl-3-azophenyl-p-sulphonamide)* (X).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide and  $\beta$ -naphthol were coupled together in quantities and manner as detailed under (IX) when a red powder, m.p. 258° (decomp.), was obtained, yield 1.7 g. (Found: N, 12.0; S, 9.6. C<sub>34</sub>H<sub>26</sub>O<sub>6</sub>N<sub>6</sub>S<sub>2</sub> requires N, 12.42; S, 9.41 per cent).

*Ethylene-bis-N<sup>1</sup>-(4-aminobenzeneazophenyl-p-sulphonamide)* (XI).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1 g.) was tetrazotised as described under (I) and coupled with aniline (0.5 g.), dissolved in hydrochloric acid (10%, 3 c.c.) at 0°. Sodium acetate (7 g.) in water (15 c.c.) was then added to remove the mineral acid in excess, and the mixture kept overnight. The red precipitate that had separated was filtered, washed with water and alcohol and finally dried. The product could not be crystallised from usual organic solvents and obtained as a red powder, m.p. 185° (decomp.), yield 1.5 g. (Found: N, 18.88; S, 10.7. C<sub>28</sub>H<sub>26</sub>O<sub>4</sub>N<sub>6</sub>S<sub>2</sub> requires N, 19.37; S, 11.07 per cent).

*Ethylene-bis-N<sup>1</sup>-(5-methyl-2-aminobenzeneazophenyl-p-sulphonamide)* (XII).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1 g.) was tetrazotised and coupled with *p*-toluidine (0.6 g.) as under (XI). It was finally obtained as a brick-red powder decomposing above 135°, yield 1.5 g. (Found: N, 18.95. C<sub>28</sub>H<sub>30</sub>O<sub>4</sub>N<sub>6</sub>S<sub>2</sub> requires N, 19.24 per cent).

*Ethylene-bis-N<sup>1</sup>-(2-amino-5:6-dimethylbenzeneazophenyl-p-sulphonamide)* (XIII).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1 g.) was tetrazotised and coupled with *p*-xyldine (0.6 g.) as under (XI) to give a brick-red dye, m.p. 138° (decomp.), yield 1.6 g. (Found: N, 17.25. C<sub>30</sub>H<sub>34</sub>O<sub>4</sub>N<sub>6</sub>S<sub>2</sub> requires N, 17.66 per cent).

*Ethylene-bis-N<sup>1</sup>-(4-dimethylaminobenzeneazophenyl-p-sulphonamide)* (XIV).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1 g.) was tetrazotised and coupled with dimethylaniline (0.7 g.) to give an orange-red powder as under (XI), m.p. 253° (decomp.), yield 1.5 g. (Found: N, 17.34. C<sub>30</sub>H<sub>34</sub>O<sub>4</sub>N<sub>6</sub>S<sub>2</sub> requires N, 17.66 per cent).

*Ethylene-bis-N<sup>1</sup>-(2-amino-4-hydroxybenzeneazophenyl-p-sulphonamide)* (XV).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1 g.) was tetrazotised and coupled with *m*-aminophenol (0.6 g.) as under (XI) to give a reddish yellow powder, m.p. 176° (decomp.), yield 1.4 g. (Found: N, 17.65. C<sub>26</sub>H<sub>26</sub>O<sub>6</sub>N<sub>6</sub>S<sub>2</sub> requires N, 18.36 per cent).

*Ethylene-bis-N<sup>1</sup>-(5-methoxy-2-aminobenzeneazophenyl-p-sulphonamide)* (XVI).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1 g.) was tetrazotised and coupled with *p*-anisidine (0.7 g.)

to give a reddish yellow powder as under (XI), m.p.  $140^{\circ}$  (decomp.), yield 1.5 g. (Found : N, 17.1.  $C_{28}H_{30}O_6N_8S_2$  requires N, 17.55 per cent).

*Ethylene-bis-N<sup>1</sup>-(3-carboxylic-4-aminobenzeneazophenyl-p-sulphonamide)* (XVII).—*Ethylene-bis-N<sup>1</sup>-sulphanilamide* (1 g.) was tetrazotised and coupled with anthranilic acid (0.75 g.) as in (XI). A yellow powder was obtained, m.p.  $160^{\circ}$  (decomp.), yield 1.7 g. (Found : N, 16.25.  $C_{28}H_{26}O_8N_8S_2$  requires N, 16.81 per cent).

*Ethylene-bis-N<sup>1</sup>-(2:4-diaminobenzeneazophenyl-p-sulphonamide)* (XVIII).—*Ethylene-bis-N<sup>1</sup>-sulphanilamide* (1 g.) was tetrazotised and coupled with phenylenediamine hydrochloride (1 g.) in water (5 c.c.) as in (XI) to yield a brown powder, m. p.  $223^{\circ}$  (decomp.), yield 1.7 g. (Found : N, 22.60.  $C_{26}H_{28}O_4N_{10}S_2$  requires N, 23.02 per cent).

*Ethylene-bis-N<sup>1</sup>-(2-aminonaphthylazophenyl-p-sulphonamide)* (XIX).—*Ethylene-bis-N<sup>1</sup>-sulphanilamide* (1 g.) was tetrazotised and coupled with  $\beta$ -naphthylamine (0.8 g.) as in (XI). The product was obtained as a red powder, m.p.  $210^{\circ}$  (decomp.), yield 1.7 g. (Found : N, 16.09.  $C_{31}H_{30}O_4N_8S_2$  requires N, 16.15 per cent).

*Ethylene-bis-N<sup>1</sup>-(1-amino-4-sulphonic-naphthylazophenyl-p-sulphonamide)* (XX).—*Ethylene-bis-N<sup>1</sup>-sulphanilamide* (1 g.) was tetrazotised and coupled with naphthionic acid (1.1 g.) as in (XI) to give a dark red powder decomposing above  $250^{\circ}$ , yield 1.5 g. (Found : N, 12.92.  $C_{34}H_{30}O_{10}N_8S_4$  requires N, 13.36 per cent).

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# SYNTHESIS OF PARA-AMIDINOPHENYLSTIBINIC ACID

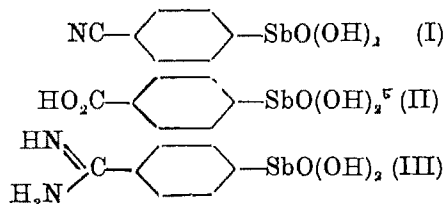
By T. N. GHOSH AND S. BANERJEE

In an attempt to obtain compounds of enhanced therapeutic activity and low toxicity for the treatment of Kala-azar, *p*-amidinophenylstibinic acid has now been synthesised.

The direct trypanocidal action of synthalin (decamethylenediguanidine dihydrochloride) was first demonstrated by Lourie and Yorke (*Ann. Trop. Med. Parasit.*, 1937, 31, 435). Later King, Lourie and Yorke (*Lancet*, 1937, 283, 136) prepared and examined a number of compounds related to synthalin and found that symmetrical diamidinoalkanes exhibited an even greater trypanocidal action than that of the corresponding guanidine derivatives. In view of these observations, a large number of aromatic diamidines has been synthesised by Ashley, Barber, Ewins, Newbery and Self (*J. Chem. Soc.*, 1942, 103) in the hope that such compounds may exhibit increased trypanocidal action. Among the aromatic diamidines, synthesised by these workers, 4:4'-diamidinostilbene and 4:4'-diamidinodiphenoxypentane have been successfully employed for the treatment of Mediterranean Kala-azar (Kirk and Sati, *Ann. Trop. Med. Parasit.*, 1940, 34, 82; Kirk and MacDonald, *ibid.*, 1940, 34, 131) and of Indian Kala-azar (Adams and Yorke, *ibid.*, 1939, 33, 323; 1940, 34, 174). This discovery has opened up a new vista in the chemotherapy of Kala-azar.

Derivatives of *p*-aminophenylstibinic acid, such as, urea stibamine, diethylamine-*p*-aminophenylstibinate, etc., have been found to be potent drugs for the treatment of Kala-azar. Although the former drug is widely used in India for the treatment of Kala-azar, it has two drawbacks, namely, its variable constitution and its instability. Moreover, this drug at times does show toxic reaction. In an attempt to obtain compounds of enhanced therapeutic activity and low toxicity for the treatment of Kala-azar, it has been considered to be of great interest to synthesise and pharmacologically examine *p*-amidinophenylstibinic acid, a compound containing both the amidino and phenylstibinic acid groups.

Pure *p*-aminophenylstibinic acid is diazotised and the diazo solution treated with cuprous cyanide solution when *p*-cyanophenylstibinic acid (I) is formed. The cyano compound has been purified by trituration with glacial acetic acid which dissolves any unreacted *p*-aminophenylstibinic acid. The compound (I) is hydrolysed by concentrated alkali to *p*-carboxyphenylstibinic acid (II). The cyano compound (I) has been converted into *p*-amidinophenylstibinic acid (III) via the corresponding imino-ether (cf. Linsker and Bogert, *J. Amer. Chem. Soc.*, 1933, 55, 932)



## EXPERIMENTAL

*p*-Cyanophenylstibinic Acid (I) — *p*-Aminophenylstibinic acid, prepared according to the well known method of Dunning and Reid (*J. Amer. Chem. Soc.*, 1926, 48, 2959; American Patent, No. 1682269), is always contaminated with varying quantities of *p*-acetylaminophenylstibinic acid (Gray, Trevan, Bainbridge and Atwood, *Proc. Roy. Soc.*, 1931, B, 108, 54). Both *p*-aminophenylstibinic acid and its acetyl derivative are readily soluble in glacial acetic acid; the former, however, slowly dissolves in dilute hydrochloric acid, in which the acetyl derivative is insoluble. The amino compound was therefore purified by trituration with a large excess of *N*/4-hydrochloric acid, filtration, treatment of the filtrate with concentrated alkali till faintly acid, and finally by precipitation with sodium acetate. This operation was carried out twice and the *p*-aminophenylstibinic acid, thus obtained in a pure form, was kept in a slightly moist condition before it was used, otherwise it tended to decompose in a dry state.

Pure *p*-aminophenylstibinic acid (50 g.) was treated with hydrochloric acid (750 c.c.) and diazotised, under ice-cooling, with 3*N*-sodium nitrite solution (67 c.c.). The diazonium chloride solution was slowly poured, under brisk stirring, into a warm (70°) solution of copper sulphate (50 g.), potassium cyanide (56 g.) and water (300 c.c.). and the mixture was kept in a cold room overnight. Next day, the mixture was filtered and then concentrated under reduced pressure to a volume of 125 c.c. After adding 20 c.c. of concentrated hydrochloric acid, *p*-cyanophenylstibinic acid was filtered and washed with hydrochloric acid and then with water. The solid was dried in air and then triturated with glacial acetic acid, filtered, washed with excess of water and dried in air, yield 10 g. The solid was further purified by solution in dilute alkali and reprecipitation with excess of dilute hydrochloric acid. It is soluble in hot water, from which it is obtained as a colourless powder, which does not melt even at 320°. (Found: N, 4.79; Sb, 43.98.  $C_7H_6O_3NSb$  requires N, 5.11; Sb, 44.47 per cent). It is insoluble in dilute acids but readily soluble in alkali, and does not contain any diazotisable amino group.

The solid mixed with cuprous cyanide, as described above, was thoroughly triturated with an excess of 10% hydrochloric acid, filtered, washed with water and dried. The solid was next triturated with excess of glacial acetic acid, filtered and washed with water. The compound (5 g.) was proved to be *p*-cyanophenylstibinic acid after purification as described above.

*Carboxyphenylstibinic Acid* (II).—The above compound (I, 5g.) was heated on the wire-gauze under reflux with 27% sodium hydroxide solution (60 c.c.) for 3 hours, when ammonia was evolved. The solution was cooled in ice and acidified with dilute hydrochloric acid. The precipitate was filtered and washed thoroughly with water. It is insoluble in hot water and in ordinary organic solvents. It was purified by solution in alkali and precipitation with hydrochloric acid, when, on drying *in vacuo* at 130° for 3 hours, a white powder was obtained which did not melt even at 320°, yield 3g. [Found: Sb, 41.28; M.W. (by titration), 288.  $C_7H_5O_3Sb$  requires Sb, 41.59 per cent. M. W., 292.76]. It does not contain any nitrogen and is found to form di-sodium salt, as determined by



titration with standard sodium hydroxide solution till a neutral reaction is obtained (phenolphthalein as indicator).

*p*-Amidinophenylstibinic Acid (III).— The above compound (I, 10 g.) was finely powdered and suspended in dry ether (20 g.), to which absolute alcohol (6 g.) was added. The mixture was then saturated with dry hydrochloric acid gas at 0° and the flask was then well-stoppered and left in a refrigerator for 6 days, when the imino-ether hydrochloride separated as a grey powder, which was filtered off, washed with dry ether and dried in a vacuum desiccator, yield 6.5 g. It does not melt even at 300°.

The above imino-ether hydrochloride (6 g.) was finely powdered and treated with 10% alcoholic ammonia (60 c.c), and the mixture was heated in a closed vessel at 60-65° for 5 hours. After cooling overnight, the chocolate coloured precipitate of the amidine hydrochloride was filtered, washed with alcohol and dried in a vacuum desiccator. It does not melt even at 300°. It was then triturated with very dilute hydrochloric acid and the solution after filtration was carefully treated with dilute ammonium hydroxide, when a brown amorphous precipitate of the free amidine was obtained. The addition of dilute ammonium hydroxide was continued till maximum precipitation was obtained. The solid (3g.) was purified by solution in dilute hydrochloric acid and precipitation with just the requisite quantity of ammonia. It was filtered, washed with water, and dried. (Found: N, 9.24; Sb, 42.18.  $C_7H_5O_3N_3$  Sb requires N, 9.63; Sb, 41.87 per cent). It is soluble both in dilute mineral acids and alkalis but practically insoluble in hot water and in ordinary organic solvents, and does not melt even at 300°.

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## A NOTE ON THE MOVEMENT OF CAMPHOR ON WATER

By B. S. SRIKANTAN

Raleigh (*Proc. Roy. Soc.*, 1890, **A**, 47, 364) found that to stop the motion of camphor on water, a lowering of surface tension by 16 dynes was required. This phenomenon has been studied by a number of other investigators (Miss Pockels, *Nature*, 1891, **43**, 437; Ramdas, *Indian J. Phys.*, 1926, **1**, 1). Edwards (*J. Chem. Soc.*, 1925, 144), Gelpert (*Z. Physik*, 1919, **29**, 78) and others have shown that other organic substances also behave in a similar manner. An attempt has been made in this paper to gain some definite information on the subject, with reference to the size and shape of the moving piece of camphor and also the effect of temperature and pressure.

The camphor used in these experiments was a pure synthetic one from B. D. H. having m. p. of 175°.

The motion of camphor on water could be resolved into two types: (1) rotatory in which the particles swim round their own axes at a rapid rate, and (2) translatory in which the particles swim around the trough of water keeping close to the walls of the vessel. The first type of motion is always observed with smaller particles, while the bigger ones move round, the former type of motion being almost absent. The behaviour of a tiny speck of camphor on a drop of water, if viewed under the microscope, is interesting. At first the edges of the crystal vanish and the particle assumes a smooth rounded shape. As the edges go off, the particle tends to move in the opposite direction. The edges and the corners of the crystal are more susceptible to volatilisation than the mass. The resultant of a series of recoil forces due to this volatilisation should be acting as a couple at the ends producing a rotatory motion. A simple analogous experiment with solid carbon dioxide illustrates the point.

Specks of solid carbon dioxide, loosely held together (but not compressed), if thrown in a trough of water, float on it and as carbon dioxide rapidly sublimates, the specks rotate violently. There is no translatory motion.

Next, pieces of camphor 2 (mm. thickness) of various geometrical shapes were tried. Squares of 1 cm. side, circular pieces of 1 cm. diameter, and crescent shaped pieces of 1 cm. chord were made by pressing into shape in wooden moulds. Thus the perimeter was varied. All of them, except the crescent shaped one, exhibited more of translatory motion than rotatory one. The crescent shaped pieces rotated violently, and swam around only when the corners were blunt due to volatilisation. They did not show motion away from the concave side as claimed by Ramdas (*loc. cit.*). In all these experiments water was absolutely free from grease or any speck of camphor other than the one under observation. Every time an experiment was performed, fresh water was used.

Though in all these pieces the perimeter was different from one another, all of them at 25° swam with an average velocity of 3.5 cm. per second. Pieces pressed hard into spherical shapes showed no motion at all. But those pressed

between non-greasy and dry fingers, so that they were flat, with the central portion more compressed than the edges, swam with greater velocity than those made in the press under pressure. They had an average velocity of 4.6 cm. per second. The loose edges having greater chances of volatilisation are responsible for this increased velocity. Hence in the following experiments only such pieces were taken. The average velocity in these experiments was calculated from the number of times the circumference of the trough was traversed in 5 minutes; troughs of different diameters were also used.

*Temperature.*—Experiments were performed at a constant temperature in a thermostat having accuracy of  $\pm 0.1^\circ$ . The following table shows the effect of temperature on the motion of camphor.

TABLE I

Temp. .. ..	15°	25°	30°	40°
Velocity (cm./sec.)	1.0	4.6	7.0	There is only feeble rotatory motion but no translatory motion.

*Pressure.*—Experiments were next conducted under the cover of a bell jar attached to a suction pump and a vacuum gauge. The enclosure was kept at various pressures and the behaviour of camphor was observed. After each observation the water was changed and the bell jar cleaned and kept exposed to air for a considerable length of time to drive off the smell of camphor inside it. The results are given in Table II.

Table II

Temp. =  $25^\circ$ .

Pressure. (cm.)	....	76	56	44	39
Velocity (cm./sec.)	....	4.3	2.4	2.1	1.9

The motion decreased with lowering of air pressure, the rate of fall was, however, far from being proportional. A bell jar containing vapour of camphor sublimed into it was brought over the trough of water on which the camphor was moving. The motion was at once arrested and the piece of camphor stopped moving.

From the above experiments it is clear that the perimeter or the geometrical shape of the piece of camphor does not seem to be important. The rotatory motion is due to the volatilisation of camphor giving rise to a couple acting on the piece.

Miss Pockels (*loc cit.*) explains the movement of camphor on water as due to the greater insolubility of surface than that in the bulk of the solvent and consequent changes in surface tension. This is in consonance with the thermodynamically derived equation of Gibbs, if one identifies the surface concentration with the phenomenon of adsorption. A Langmuir-Taylor type of surface forces on water might be imagined with the possibility of lateral shift of the adsorbed molecule of camphor vapour to a final position of minimum energy. The lateral shift of the adsorbed molecule of camphor vapour produces a recoil on the main piece giving it a translatory motion.

At 40° and above, the process of evaporation of water is rapid and molecules of water at the surface evaporate away rapidly leaving a surface which is not capable of imparting any lateral shift to the adsorbed molecules. Hence the result in Table I. As could be expected from this reasoning, the activity of camphor in water is less when the vessel is evacuated, since even in this case the evaporation of the more active surface molecules leaves a surface with poor capacity for adsorption. Further saturated vapour of camphor, as in the bell jar experiment, arrests the motion of camphor in a striking manner. This is due to the surface of water being saturated at once with camphor vapour and hence no chance for a lateral shift occurs.

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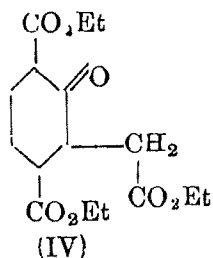
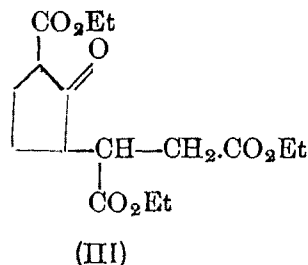
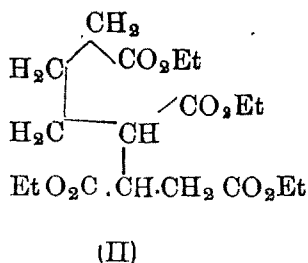
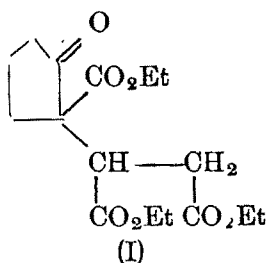
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SYNTHETIC INVESTIGATIONS IN THE FUSED RING SYSTEMS.  
PART I. STUDIES ON THE MICHAEL CONDENSATION  
BETWEEN ETHYL *CYCLOPENTANONE*-2-CARBO-  
XYLATE AND DIETHYL MALEATE

BY (LATE) K. C. GHOSH

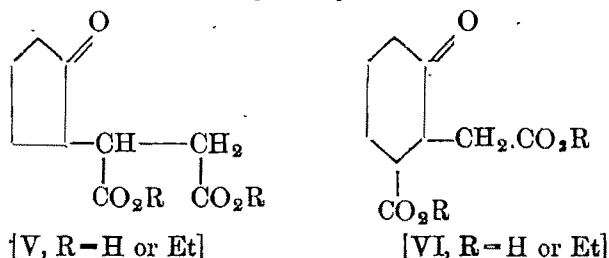
Michael condensation between ethyl *cyclopentanone*-2-carboxylate and diethyl maleate has been studied with different condensing agents.

In this paper, the observations that have been made while carrying out the Michael condensation between *cyclopentanone* carboxylate and maleic ester have been described. The condensation was first carried out between *cyclopentanone* carboxylate and maleic ester with a small quantity of potassium ethoxide in the cold in an ether-alcoholic solution. Yield of the higher boiling product, thus obtained, was almost quantitative. From the analytical data, it cannot be decided whether the condensation takes place normally to yield the  $\beta$ -ketonic system (I) or the tetra-ester (II).



To determine the constitution of the condensation product it has been hydrolysed with concentrated hydrochloric acid and the gummy acid obtained has been esterified. The ester thus formed is found to have the same boiling point and combustion data as of the original condensation product. Further, the tetra-ester (II) undergoes Dieckmann condensation on treatment with sodium dust. The ring-closure can take place in two ways, leading to the formation of either a five-membered (III) or a six-membered (IV) system. The  $\beta$ -ketonic ester is hydrolysed

with concentrated hydrochloric acid when a solid keto-acid is obtained; the latter is esterified. The acid or its ester may be represented by either (V) or (VI).



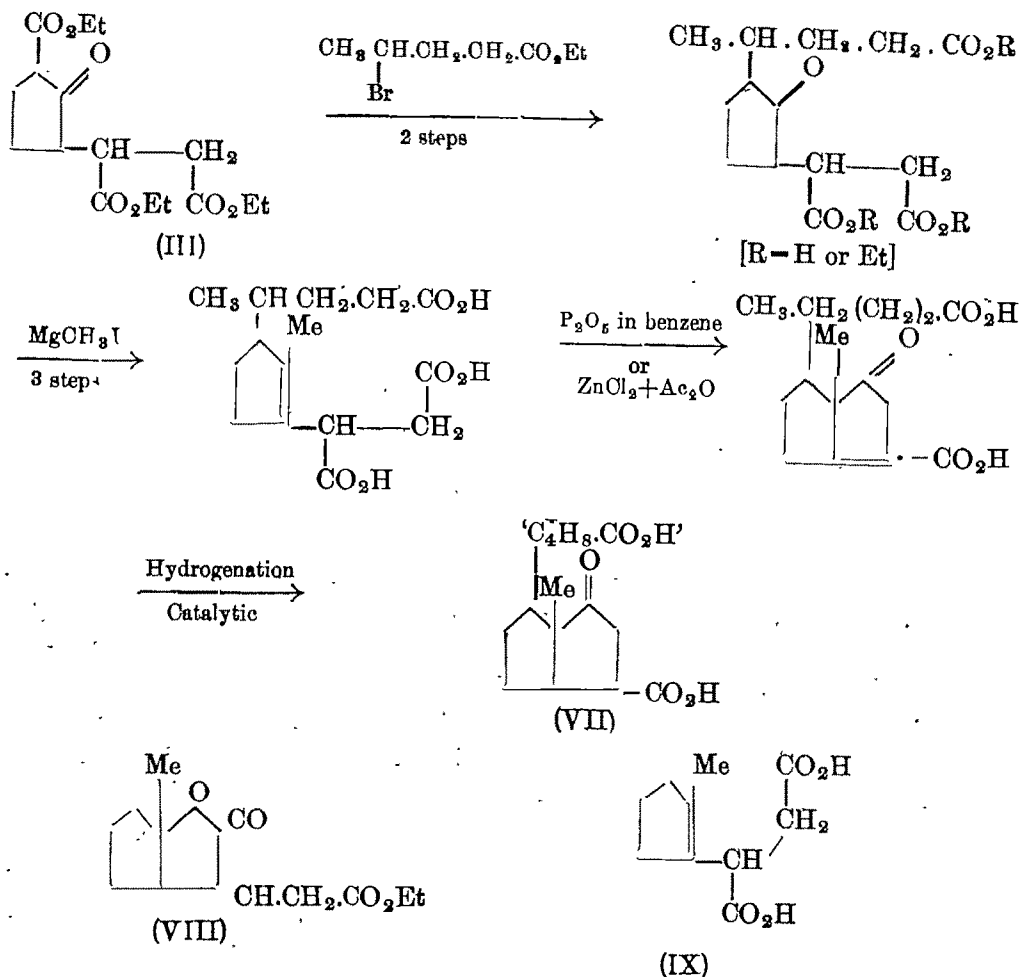
*cyclopentanone* carboxylate has been condensed with maleic ester in presence of piperidine. The boiling point of the condensation product is found to be lower than that of the condensation product obtained when potassium ethoxide is used as the condensing agent. The yield of the condensation product in this case is satisfactory; further, the unchanged materials can be recovered and recondensed with piperidine. The condensation product is hydrolysed with concentrated hydrochloric acid when a solid keto-acid is obtained. This acid has been found to be identical with the solid acid derived from the hydrolysis of the  $\beta$ -ketonic ester obtained by the cyclisation of the tetra-ester (II). The acid has been esterified and the ester and its semicarbazone are also found to be identical with the di-ester (V) or (VI), and its semicarbazone.

Finally *cyclopentanone* carboxylate has been condensed with maleic ester in presence of a trace of sodium ethoxide. The condensation product, obtained in very poor yield, has a boiling point lower than that of the condensation product obtained by the use of potassium ethoxide as the condensing agent. The condensation product on hydrolysis with concentrated hydrochloric acid also yields a solid keto-acid which is found to be identical with the acid obtained by the hydrolysis of (i) the  $\beta$ -ketonic ester (III or IV) and (ii) the condensation product obtained using piperidine as the condensing agent. The ester of this acid and its semicarbazone are found to be identical with the di-ester (V) or (VI) and its semicarbazone.

In view of the above results, it is concluded that the condensation between ethyl *cyclopentanone* carboxylate and maleic ester in presence of a trace of sodium ethoxide and piperidine proceeds in the normal manner to yield the Michael product (I), but in presence of potassium ethoxide (0.1M) the tetra-ester (II) is formed. Further, this ester (II) on cyclisation by means of sodium yields the five membered  $\beta$ -ketonic ring system (III).

The investigation of the above reactions was undertaken with a view to synthesising the pyroketo acid (VII) obtained by Wieland *et al.*, through the oxidative degradation of desoxycholic acid. It seems that the  $\beta$ -keto ester (III) is eminently suitable as a starting material for such a synthesis. It was expected that the  $C_4H_8CO_2H$  group belonging to (VII) could be introduced by reacting the above  $\beta$ -keto ester with the appropriate ester halide followed by hydrolysis. Further, it is intended to introduce the necessary angular methyl group by reacting the keto-ester derivative with magnesium methyl iodide followed by dehy-

dration, hydrolysis and final ring-closure. Above series of reactions may be schematically represented as follows :



As a preliminary to the above objective, Grignard complex of methyl iodide has been reacted with the keto-ester (V). On working up the reaction product a lactone, probably (VIII), is obtained. It has, however, not been possible to convert (VIII) into the required unsaturated acid (IX) due to the easy formation of the lactone even in the cold. Further treatment of the lactonic ester (VIII) with baryta with subsequent reaction of the dry barium salt with  $\text{PCl}_5$ , followed by treatment with stannic chloride in carbon disulphide solution in the cold, according to the method of Haberland (*Ber*, 1939, 72 1221, 1226), did not yield the desired ketonic product.

#### EXPERIMENTAL

*Ethyl n-Hexane-1:2:3:6-tetracarboxylate*.—Potassium (0.4 g.) was pulverised under xylene, xylene was replaced by ether and cooled in a freezing mixture,

Alcohol (55 c.c.) was added and when all the potassium had reacted with alcohol, a mixture of *cyclopentanone* carboxylate (15.6 g.) and maleic ester (17.2 g.) was added and the reaction mixture after keeping for 3 days at the room temperature, was poured into ice-cold acidulated water. The precipitated oil was extracted with ether, the extract well washed with water, dried and the ether removed. The residue was distilled, when hardly any unchanged material could be obtained and the distillate boiled at  $182^{\circ}/4\text{mm}$ , yield 36 g. [Found : C, 58.0; H, 7.86  $\text{C}_{18}\text{H}_{30}\text{O}_8$  (II) requires C, 57.7; H, 8.02 per cent and  $\text{C}_{16}\text{H}_{24}\text{O}_7$  (I) requires C, 58.5; H, 7.32 per cent).

The above product was refluxed with 150 c. c. of concentrated hydrochloric acid for 12 hours. The clear aqueous solution was evaporated to dryness on a water-bath. The thick syrupy liquid was then esterified by refluxing with 100 c. c. of alcohol and 12 c. c. of concentrated sulphuric acid for 24 hours. The product after dilution with cold water was extracted with ether and the ethereal solution was washed with water, bicarbonate solution and water again. Ether was removed and the residue was distilled at  $182-83^{\circ}/4\text{ mm.}$ , yield 30 g. (Found : C, 57.9; H, 7.87.  $\text{C}_{18}\text{H}_{30}\text{O}_8$  requires C, 57.7; H, 8.02 per cent).

*Ethyl 2-Keto-3-carbethoxycyclopentylsuccinate*.—The above tetra-basic ester (II, 20 g.) was refluxed with sodium dust (2.8 g.) in dry benzene till the bright surface of sodium could not be detected. The cooled reaction mixture was treated with ice and hydrochloric acid. The benzene layer was separated, washed with water, sodium bicarbonate solution and again with water, solvent removed and distilled in vacuum, b. p.  $165-70^{\circ}/4\text{ mm.}$ , yield 21 g. (Found : C, 58.2; H, 7.30.  $\text{C}_{16}\text{H}_{24}\text{O}_7$  requires C, 58.5; H, 7.32 per cent). It gave a positive ferric reaction.

*Ethyl 2-Ketocyclopentylsuccinate*.—The above  $\beta$ -ketonic ester was hydrolysed by refluxing with 100 c. c. of concentrated hydrochloric acid for 24 hours and the whole mass was transferred to a porcelain basin and evaporated to dryness when a solid acid was obtained. On crystallisation from benzene it melted at  $134-36^{\circ}$ , after shrinking at  $120^{\circ}$ . (Found : C, 53.6; H, 5.96.  $\text{C}_9\text{H}_{12}\text{O}_5$  requires C, 54.0; H, 6.0 per cent).

The acid was esterified by refluxing with alcohol (50 c. c.) and sulphuric acid (6 c. c.) for 24 hours. On working up in the usual way the product distilled at  $155-60^{\circ}/5\text{ mm.}$ , yield 10 g. The *semicarbazone* was prepared by warming two drops of this ester with an alcoholic solution of semicarbazide hydrochloride and sodium acetate. On crystallisation from aqueous alcohol, it melted at  $118^{\circ}$ . (Found : C, 60.6; H, 7.80  $\text{C}_{13}\text{H}_{20}\text{O}_5$  requires C, 60.9; H, 7.81 per cent).

*Ethyl 1-Carbethoxy-2-ketocyclopentylsuccinate*.—(a) A mixture of *cyclopentanone* carboxylate (60 g.) and maleic ester (66 g.) was taken in a flask fitted with a cork and calcium chloride guard tube, and to the mixture were added 20 c. c. of piperidine when the mixture became quite hot. It was heated on a water-bath for 16 hours, cooled and poured into iced hydrochloric acid. The oil was extracted



with ether and washed with water, dried and ether removed and the residue distilled. The fraction boiling at  $165-70^{\circ}/5$  mm. was collected, yield 75 g. The unchanged material can be recondensed with piperidine to obtain further quantities of the condensation product. (Found : C, 58.2 ; H, 7.38.  $C_{16}H_{24}O_7$  requires C, 58.5 ; H, 7.32 per cent).

The above ester (75 g.) was refluxed with 300 c. c. of concentrated hydrochloric acid for 36 hours. The hydrolysed product was evaporated to dryness in a porcelain basin on a water-bath when the same solid acid (V) was obtained. This acid was esterified by refluxing with alcohol (200 c. c.) and sulphuric acid (24 c. c.) for 36 hours. On working up, the product distilled at  $155-60^{\circ}/5$  mm., yield 39 g. It gave a semicarbazone of m.p.  $113^{\circ}$  which was found to be identical with the semicarbazone of (V). (Found : C, 60.6 ; H, 7.76.  $C_{18}H_{20}O_5$  requires C, 60.9 ; H, 7.81 per cent).

(b) *cyclopentanone* carboxylate (15.6 g.) in alcohol (33 c. c.) was added to a well cooled solution of a trace of sodium ethoxide dissolved in alcohol (10 c. c.). The mixture was cooled in a freezing mixture. Then another solution of maleic ester (17.2 g.) in alcohol (20 c. c.) was cooled and added to the previously cooled mixture and the whole thing was left overnight. On working up, only 5 g. of the high boiling product ( $165-170^{\circ}/5$  mm.) were obtained. (Found : C, 58.0 ; H, 7.36.  $C_{16}H_{24}O_7$  requires C, 58.5 ; H, 7.32 per cent).

The above ester was hydrolysed by refluxing with 40 c. c. of concentrated hydrochloric acid for 24 hours. On evaporation of the hydrolysed product the solid keto-acid (V) was obtained. The acid was esterified with 25 c. c. of alcohol and 3 c. c. concentrated sulphuric acid ; on working up in the usual way 2.5 g. of the distillate (b.p.  $155-60^{\circ}/5$  mm.) were obtained. It gave a semicarbazone, m.p.  $118^{\circ}$  (mixed m.p. with the semicarbazone of the ester, V). (Found : C, 61.0 ; H, 7.79.  $C_{18}H_{20}O_5$  requires C, 60.9 ; H, 7.81 per cent).

*Lactone of 2-Methyl-2-hydroxycyclopentylsuccinic Semiethyl Ester-acid.*—Methyl iodide (8 c. c.) was dropped slowly and carefully on 2.3 g. of magnesium in absolute ether (30 c. c.). After the reaction was complete, 20 g. of the keto-ester, diluted with dry ether, were taken in a flask, cooled in an ice-bath. The Grignard's complex in ether was added dropwise, when white solids separated ; the whole mass was kept overnight. It was decomposed with iced hydrochloric acid, extracted with ether, the ethereal layer was washed with water and cold dilute NaOH solution and next with water. The ethereal layer was dried, the solvent was removed and distilled, b.p.  $160^{\circ}/4$  mm., yield 10.1 g.

By the above reaction, the tertiary alcohol might have been formed ; but the analytical data (given below) did not correspond with the alcohol but with the lactone (VIII). This lactone was found to be insoluble in cold dilute NaOH solution. (Found : C, 63.2 ; H, 7.92.  $C_{12}H_{18}O_4$  requires C, 63.7 ; H, 7.96 per cent).

*Hydrolysis of the Lactone (VIII) and an attempt for Ring-closure.*—The above lactone (5 g.) was refluxed with baryta solution (28 g.) and the barium salt formed was dried and treated with  $\text{PCl}_5$  (19 g.) in dry carbon disulphide, followed by treatment with stannous chloride (125 c. c.) in a freezing mixture. The reaction mixture was decomposed with ice; organic layer separated, washed with water, dried and the solvent removed. But the desired product could not be isolated from the residue.

Thanks are due to Prof. P. C. Mitter and Prof. S. N. Bose for their interest and to Dr. D. K. Banerjee for generous help during the progress of this work. Thanks are also due to Mr. N. Ghosh for micro-analyses of some of the compounds.

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SYNTHESES IN THE ACRIDINE SERIES PART III.  
N-SUBSTITUTED 4-METHOXY-7-CHLORO-9-AMINOACRIDINE

BY GURBAKSH SINGH, TARA SINGH AND GURDAS SINGH

A number of N-substituted 4-methoxy-7-chloro-9-aminoacridines (wherein both OMe and Cl have been shifted to 4 and 7 positions respectively) has been synthesised; the 9-substituted groups being dialkylamino-alkylamine, aromatic and heterocyclic amino groupings and some simple substituents like OH and COOH.

We have already described the synthesis of a number of chloromethoxy-9-dialkyl-aminoacridines (*J. Indian Chem. Soc.*, 1946, **23**, 224, 466), wherein the chlorine atom at position 6 and the methoxy group at position 2 (as present in the atebirin molecule) have been transferred to those at 5 and 4 respectively, while keeping the other fixed at its original position. In the present paper we have described the syntheses of a number of N-substituted 4-methoxy-7-chloro-9-aminoacridines, wherein both the methoxy group and chlorine atom have been shifted to positions 4 and 7 respectively. The various substituents at position 9 include certain dialkylamino-alkylamines of the type present in atebirin, some heterocyclic and aromatic amino groupings and some simple substituents like hydroxy and carboxyl. 4-Methoxy-7-chloro-9-aminoacridine has been prepared and condensed with *p*-acetylaminobenzene sulphonyl chloride.

2:5-Dichlorobenzoic acid has been condensed with *o*-anisidine to give 6'-methoxydiphenylamine-4-chloro-2-carboxylic acid, which on treatment with POCl<sub>3</sub> gives 4-methoxy-7:9-dichloroacridine. This is condensed with various amino compounds in the usual way. During the condensation of 4-methoxy-7:9-dichloroacridine with some simple amino compounds like ethanolamine, urethane, piperazine, and ethylenediamine, the acridine is converted quantitatively into the corresponding acridone and no condensation product could be isolated. This difficulty has been overcome and the desired compounds are obtained through the acid chloride. In general, the route to the compounds of atebirin type also, through the diphenylamine-*o*-carboxylamide, is extremely convenient one, the reaction proceeding very smoothly with good yields. No acridones are obtained. The intermediate amides could be isolated in a number of cases, but have not been done so, except in the case of condensation with ethanolamine.

## E X P E R I M E N T A L

*6'-Methoxy-4-chlorodiphenylamine-2-carboxylic Acid*.—After a number of preliminary experiments varying the solvents and temperature etc. the following conditions were found to give the best results. A mixture of potassium salt of 2:5-dichlorobenzoic acid (22.9 g., 1 mol.), *o*-anisidine (18.4 g., 1.5 mol.), precipitated copper (0.2 g.) and cuprous chloride (0.2 g.) was refluxed with *isoamyl* alcohol (30 c.c.) for 2 hours. Steam was passed into the reaction mixture, which removed all the *isoamyl* alcohol and any unreacted *o*-anisidine. The residue was boiled with sodium bicarbonate (10. g.) (charcoal) and filtered. On decomposition with hydrochloric acid, a greenish yellow product was obtained. Another reprecipitation through the potassium salt gave the product in yellow form, yield 80%. It was crystallised from glacial acetic acid in glistening pale yellow needles, m. p. 200-1°. (Found: N, 4.98.  $C_{14}H_{11}O_3NCl$  requires N, 5.04 per cent).

*6'-Methoxy-4-chlorodiphenylamine-2-carboxyl chloride* was obtained in the usual way by treating the diphenylamine acid with  $PCl_5$  (1:1 mol. ratio), using absolute petroleum ether (40-60°) as the reaction medium. It was crystallised from light petroleum ether in yellow needles, m.p. 101°. (Found: N, 4.70.  $C_{14}H_{11}O_2NCl$  requires N, 4.73 per cent).

*4-Methoxy-7:9-dichloroacridine*.—*6'-Methoxy-4-chlorodiphenylamine-2-carboxylic acid* (5 g) was refluxed with phosphoryl chloride (35 c.c.) at 130° for 4 hours. After removing excess of phosphorus oxychloride under vacuum, the brownish residue was cooled externally in ice and treated with excess of ice-cold ammonia solution. A yellow product was obtained which was thoroughly triturated with ammonia solution and then dried in a vacuum desiccator. It was crystallised from absolute benzene in golden yellow needles, m.p. 183-84°, yield 75%. (Found: N, 5.10.  $C_{14}H_9O NCl_2$  requires N, 5.03 per cent). This acridine is fairly unstable and hydrolyses to the corresponding acridone, after being left exposed for about 72 hours. The change occurs even in a sealed tube after some time. After crystallisation it was immediately used for condensation.

Compounds Nos. 1-7 were prepared according to the general procedure (I), 8 to 20 according to procedure (II), and those numbering 21 to 24, according to procedure (III).

(1) *4-Methoxy-7-chloro-9-(γ-diethylaminopropyl)aminoacridine* (General Procedure I).—A mixture of 4-methoxy-7:9-dichloroacridine (2.78 g., 1 mol.) dissolved in phenol (10 g.) and γ-diethylaminopropylamine (1.3 g., 1 mol.) was heated at 100° for 3 hours. After cooling, it was diluted with 100 c.c. of ether and phenol was removed by washing with 2*N*-sodium hydroxide solution. The ethereal extract was then treated with dilute acetic acid (30 c.c.), when the base passed to the aqueous layer.

Ether was removed and the acetate was decomposed with alkali and the base taken up in ether. After drying over fused potassium carbonate, the dihydrochloride was precipitated by the addition of alcoholic hydrogen chloride. It was crystallised from a mixture of absolute ethanol and ether as a deep yellow powder, m.p. 205-07° (decomp.). It is soluble in water and in alcohol. (Found : N, 9.32.  $C_{21}H_{28}ON_3Cl$ , 2HCl requires N, 9.44 per cent).

(2). *4-Methoxy-7-chloro-9-( $\delta$ -diethylaminobutyl) aminoacridine dihydrochloride* was crystallised from a mixture of absolute alcohol and ether as a deep yellow powder, m.p. 210-12° (decomp.). It is soluble in water. (Found : N, 9.25  $C_{22}H_{28}ON_3Cl$ , 2HCl requires N, 9.16 per cent).

(3) *4-Methoxy-7-chloro-9-( $\epsilon$ -diethylaminoamyl) aminoacridine dihydrochloride* was crystallised from a mixture of absolute alcohol and ether as a deep yellow powder, m.p. 204° (decomp.). It is soluble in water. (Found : N, 8.62.  $C_{23}H_{30}ON_3Cl$ , 2HCl requires N, 8.88 per cent).

(4) *4-Methoxy-7-chloro-9-( $\gamma$ -di-n-propylaminopropyl) aminoacridine*.—The dihydrochloride was twice crystallised from a mixture of absolute alcohol and ether as a yellow powder. It forms a hydrate, m.p. 114-120°. After drying in an air-oven at 100° for 4 hours, the melting point was raised to 206-08° (decomp.). (Found for anhydrous substance) : N, 8.59.  $C_{23}H_{30}ON_3Cl$ , 2HCl requires N, 8.88 per cent).

(5). *4-Methoxy-7-chloro-9-( $\gamma$ -di-n-butylaminopropyl) aminoacridine*.—The dihydrochloride was crystallised thrice from a mixture of absolute alcohol and ether as a yellow powder with solvent of crystallisation, m.p. 134-37°. The hydrate is very stable and could not be converted into the anhydrous compound even by heating at 125° for several hours under high vacuum. The hydrate was boiled with absolute alcohol for 20 minutes and excess of alcohol was then slowly evaporated on a water-bath, until a yellow powder separated. It was filtered and dried in a vacuum desiccator, m.p. 292-94° (decomp.), darkening at 250°. [Found (in the anhydrous substance) : N, 8.22  $C_{25}H_{34}ON_3Cl$ , 2HCl requires N, 8.39 per cent]

(6) *4-Methoxy-7-chloro-9-( $\gamma$ -di n-amylaminopropyl) aminoacridine*.—The dihydrochloride was thrice crystallised from absolute alcohol and ether mixture as a yellow powder. It forms a very stable hydrate which could not be converted into the anhydrous compound. It shrinks at 110° and melts at about 145°, solidifies again and then melts above 200° with decomposition. It is quite soluble in water. For analysis the meconate was prepared by treating the dry ethereal extract of the base with meconic acid dissolved in ether. A yellow powder separated, which was thoroughly washed with ether and crystallised from absolute alcohol, m.p. 205° (decomp.). (Found : N, 6.25.  $C_{27}H_{38}ON_3Cl$ ,  $C_7H_4O_7$  requires N, 6.40 per cent).

(7). *4-Methoxy-7-chloro-( $\gamma$ -piperidinopropyl) aminoacridine dihydrochloride* was crystallised from a mixture of absolute alcohol and ether in a deep yellow powder, m.p. 233-35° (decomp.). (Found : N, 9.28.  $C_{22}H_{26}ON_3Cl$ , 2HCl requires N, 9.20 per cent).

(8). *4-Methoxy-7-chloro-9-(4'-methoxyphenyl) aminoacridine*: (Procedure II).—Chloroacridine (0.5 g., 1 mol.) was dissolved in phenol (4 g.). *p*-Anisidine (0.24 g., 1.1 mols) was added and the mixture heated at 100-110° for 2 hours. After cooling, the reaction mixture was diluted with 20 c.c. of ether, when the hydrochloride separated out. It was thoroughly washed with ether and crystallised from absolute alcohol as orange-yellow, slender needles, m.p. 248-50° (decomp.). (Found: N, 7.20.  $C_{21}H_{17}O_2N_2$ , HCl requires N, 6.98 per cent). To obtain the free base, the hydrochloride was warmed with 2*N*-NaOH solution and after trituration was filtered and washed and crystallised from dilute alcohol as orange coloured needles, m.p. 165-67°.

(9). *4-Methoxy-7-chloro-9-(4'-methylphenyl) aminoacridine*—The hydrochloride was crystallised from absolute alcohol in orange-yellow needles, m.p. 260°. (Found: N, 6.96.  $C_{21}H_{17}ON_2Cl$ , HCl requires N, 7.27 per cent). The free base was crystallised from dilute alcohol as orange glistening needles, m.p. 225-27°.

(10). *4-Methoxy-7-chloro-9-(4'-ethoxyphenyl) aminoacridine*.—The hydrochloride was crystallised from alcohol as yellow needles, m.p. 258-59° (decomp.). (Found: N, 6.77.  $C_{22}H_{19}O_2N_2Cl$ , HCl requires N, 6.74 per cent).

(11). *4-Methoxy-7-chloro-9-(4'-acetylaminophenyl) aminoacridine*.—The free base was crystallised from absolute alcohol in orange-red needles, m.p. 263-64°. (Found: N, 10.85.  $C_{22}H_{18}O_2N_3Cl$  requires N, 11.10 per cent).

(12). *4-Methoxy-7-chloro-9-( $\alpha$ -naphthyl) aminoacridine*.—The hydrochloride was crystallised from absolute methyl alcohol as orange needles, m.p. 261-62° (decomp.). (Found: N, 6.82.  $C_{24}H_{17}ON_2Cl$ , HCl requires N, 6.65 per cent).

(13). *4-Methoxy-7-chloro-9-(carboxymethyl) aminoacridine*.—The condensation of 4-methoxy-7:9-dichloroacridine with glycine was carried out as described above. The product obtained was dissolved in 5% sodium hydroxide and decomposed with hydrochloric acid. Another precipitation was carried out with dilute acetic acid. The product was crystallised from 70% methyl alcohol as greenish yellow needles, m.p. 237-39°. (Found: N, 8.78.  $C_{16}H_{13}O_3N_2Cl$  requires N, 8.84 per cent).

(14). *4-Methoxy-7-chloro-9-(4'-carboxyphenyl) aminoacridine* was purified through its sodium salt as in the above case. It was crystallised from absolute alcohol as an orange-yellow powder, m.p. 277-78° (decomp.). (Found: N, 7.10.  $C_{21}H_{16}O_3N_2Cl$  requires N, 7.37 per cent).

(15). *4-Methoxy-7-chloro-9-(2'-dimethylaminophenyl) aminoacridine*—The free acridine base was crystallised from absolute alcohol as orange-red crystals, m.p. 204-5°. (Found: N, 10.95.  $C_{22}H_{20}ON_3Cl$  requires N, 11.05 per cent).

(16). *4-Methoxy-7-chloro-9-(4'-dimethylaminophenyl) aminoacridine*.—The free base was twice crystallised from absolute alcohol as an orange, microcrystalline powder, m.p. 256-58° (decomp.). (Found: N, 11.40.  $C_{22}H_{20}ON_3Cl$  requires N 11.12 per cent).

(17). 4-Methoxy-7-chloro-9-(4'-diethylaminophenyl) aminoacridine.—The base was crystallised from absolute alcohol as scarlet, slender needles, m.p. 223-25° (decomp.). (Found : N, 10.59.  $C_{24}H_{24}ON_3Cl$  requires N, 10.35 per cent).

(18). 4-Methoxy-7-chloro-9-(cyclohexyl) aminoacridine.—The hydrochloride was crystallised from glacial acetic acid in greenish yellow needles, m.p. 312-13° (decomp.). (Found : N, 7.68.  $C_{20}H_{21}ON_2Cl$ , HCl requires N, 7.42 per cent).

(19). 4-Methoxy-7-chloro-9-(p'-sulphanilaminophenyl) aminoacridine.—The free base was crystallised from a mixture of chloroform and methyl alcohol, m.p. 272-71° (decomp.) with previous darkening at 260°. (Found : N, 10.01.  $C_{20}H_{16}O_3N_3ClS$  requires N, 10.15 per cent).

(20). 4-Methoxy-7-chloro-9-(p'-arsenophenyl) aminoacridine was purified by decomposition of its sparingly soluble sodium salt with dilute acetic acid and was crystallised from methyl alcohol as an orange powder. It shrinks a little at 210° and melts with decomposition at 220-22°. (Found : N, 6.11.  $C_{20}H_{16}O_4N_2ClAs$  requires N, 6.10 per cent).

(21). 4-Methoxy-7-chloro-9-(piperidino) acridine.—The chloroacridine (0.5 g.), phenol (4 g.) and piperidine (0.2 g.) were heated in a sealed tube at 100° for 3 hours. After cooling, the mixture was poured into excess of 2N-sodium hydroxide. The yellow product obtained after trituration was filtered, and washed with water. It was crystallised from absolute alcohol as greenish yellow needles, m.p. 237-39°. (Found : N, 8.45.  $C_{16}H_{19}ON_2Cl$  requires N, 8.57 per cent).

(22). 6'-Methoxy-4-chlorodiphenylamine-2-(β-hydroxyethyl) amide : (*General Procedure III*).—A mixture of 6'-methoxy-4-chlorodiphenylamine-2-carboxyl chloride (2.96 g., 1 mol.) in absolute benzene (20 c.c.) and ethanol amine (0.61 g., 1 mol.) was warmed on a water-bath for 10 minutes, when the yellow colour disappeared. On cooling, a white product separated, which was filtered and washed with dilute ammonia. It was crystallised from alcohol as white, microcrystalline, slender needles, m.p. 141-42°. (Found : N, 8.58.  $C_{16}H_{17}O_3N_3Cl$  requires N, 8.73 per cent).

(23). 4-Methoxy-7-chloro-9-(β-hydroxyethyl) aminoacridine.—After treatment of the acid chloride with ethanolamine as described above, benzene was removed under vacuum and the residual semi-solid mass refluxed with phosphoryl chloride (6 c.c.) for 2 hours after which the unused phosphoryl chloride was removed under vacuum. The yellow residue was decomposed with dilute ammonia with cooling and the product so obtained was crystallised from dilute alcohol as golden yellow slender needles, m.p. 172-74°. (Found : N, 9.15.  $C_{16}H_{15}O_2N_2Cl$  requires N, 9.26 per cent).

(24). 4-Methoxy-7-chloro-9-(carboethoxy) aminoacridine was obtained through the acid chloride by condensation with urethane. The base obtained was crystallised from ethyl acetate as golden yellow needles, m.p. 188-90°. (Found : N, 8.20.  $C_{17}H_{15}O_3N_2Cl$  requires N, 8.47 per cent).

(25). *4-Methoxy-7-chloro-9-(piperidino)acridine* was obtained as above by condensation with piperazine (more than 2 mols.). It was crystallised from a mixture of absolute alcohol and ethyl acetate as golden yellow, slender needles, m.p. 190-92°. (Found : N, 12.62.  $C_{18}H_{18}ON_3Cl$  requires N, 12.82 per cent).

(26). *4-Methoxy-7-chloro-9-( $\beta$ -aminoethyl) aminoacridine* was obtained by the condensation of the acid chloride with excess of ethylenediamine as described above. It was crystallised from absolute ethanol as stout, yellow crystals, m.p. 172-74°. (Found : N, 13.75.  $C_{16}H_{11}ON_3Cl$  requires N, 13.93 per cent).

(27). *4-Methoxy-7-chloro-9-aminoacridine*.—*4-Methoxy-7 : 9-dichloroacridine* (2 g.) was dissolved in phenol (12 g.) at 80° and treated slowly with ammonium carbonate (2.5 g.). After the addition was complete, the temperature was raised to 130° and maintained for 20 minutes. After cooling, ether (100 c.c.) was added and the hydrochloride precipitated by passing dry hydrogen chloride. It was washed with ether and acetone. It is fairly soluble in water, from which it crystallises as a yellow powder, m.p. 290-92° (decomp.) with previous darkening at 270°. The free base obtained by the decomposition of the hydrochloride was crystallised from dilute alcohol as yellow needles, m.p. 235-37°. It is quite soluble in acetone. (Found : N, 10.71.  $C_{14}H_{11}ON_2Cl$  requires N, 10.83 per cent).

(28). *4-Methoxy-7-chloro-9-(p'-acetylaminophenylsulphonyl) aminoacridine*.—*4-Methoxy-7-chloro-9-aminoacridine* (2 g., 1 mol.) was dissolved in dry pyridine (20 c.c.). *p*-Acetylaminobenzene sulphonyl chloride (2 g., 1.5 mols.) was added slowly. A yellow powder began to separate immediately. After leaving overnight, the product was filtered and washed with dry ether. It was crystallised from a large volume of pyridine as glistening yellow crystals, m.p. 282-83° (decomp.). (Found : N 9.11.  $C_{22}H_{18}O_4N_3ClS$  requires N, 9.22 per cent).

*4-Methoxy-7-chloroacridone*.—The chloroacridine (0.4 g.) was refluxed with hydrochloric acid (5%, 30 c.c.) for 10 minutes. The white acridone that separated, after drying was crystallised from glacial acetic acid as white needles, m.p. 294-95°. (Found : N, 5.51.  $C_{14}H_{10}O_2NCl$  requires N, 5.39 per cent).

The acridone was also obtained by cyclisation of 6'-methoxy-4-chloro-diphenylamine-2-carboxylic acid with concentrated sulphuric acid.

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## ORTHO-SUBSTITUTED DIPHENYLS. PART IV. A NEW SYNTHESIS OF PHENANTHRENE

By S. A. FASHEH AND S. H. ZAHEER

*o*-Phenyl- $\alpha$ : $\beta$ -dibromocinnamic acid and *o*-phenyl- $\omega$ -bromostyrene have been prepared. The latter on treatment with aluminium chloride produces phenanthrene. The yield of phenanthrene is much improved if zinc chloride, instead of aluminium chloride, is used as a condensing agent. On treatment with alcoholic potassium hydroxide *o*-phenyl- $\omega$ -bromostyrene gives a high yield of *o*-diphenylacetylene of silver acetylide which has also been prepared.

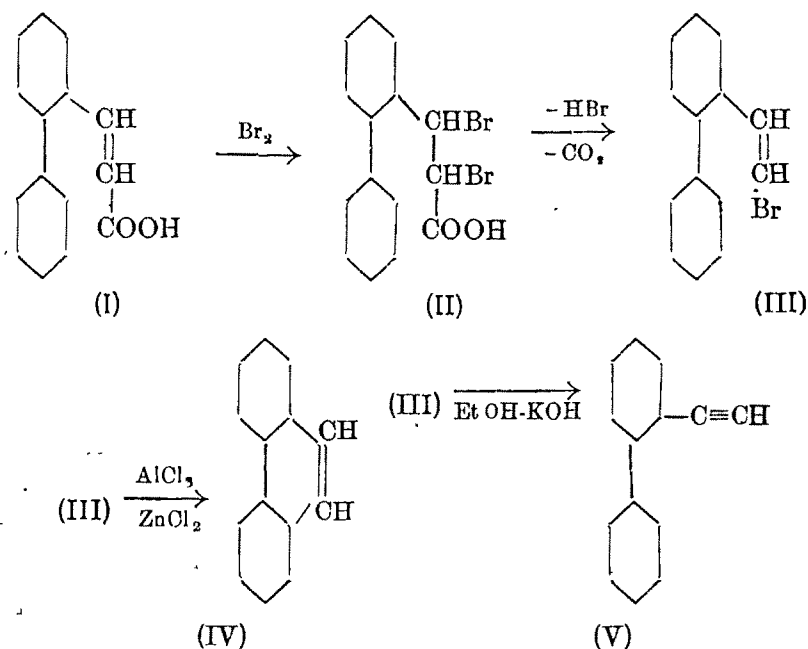
In a previous paper (*J. Indian Chem. Soc.*, 1945, 22, 181) the authors have already reported the preparation of *o*-phenyleinnamic acid and *o*-phenyl- $\alpha$ : $\beta$ -dichlorocinnamic acid, the latter by the loss of a molecule each of carbon dioxide and hydrochloric acid gave *o*-phenyl- $\omega$ -chlorostyrene which formed the starting point for a new synthesis of phenanthrene. The authors have now succeeded in obtaining the corresponding bromine derivative; the *o*-phenyl- $\alpha$ : $\beta$ -dibromocinnamic acid being obtained by the addition of a molecule of bromine to a chloroformic solution of *o*-phenyleinnamic acid. *o*-Phenyl- $\alpha$ : $\beta$ -dibromocinnamic acid, a colourless, crystalline and stable compound, readily loses on treatment with  $\text{Na}_2\text{CO}_3$  solution (moderately conc.) a molecule each of carbon dioxide and hydrobromic acid to give the corresponding *o*-phenyl- $\omega$ -bromostyrene, a light straw coloured oil, readily distillable under reduced pressure. It has been noticed that the loss of carbon dioxide and hydrohalogen acid by the treatment with sodium carbonate solution takes place much more readily in the case of the dibromo compound than with the dichloro-acid. The *o*-phenyl- $\omega$ -bromostyrene on treatment with aluminium chloride in the usual manner gives a good yield of phenanthrene. The production of phenanthrene from the chloro- as well as the bromostyrenes clearly indicates the structure of these halogen compounds; in their production from the dihalogen acid by the action of sodium carbonate, it is the  $\alpha$ -halogen and the  $\beta$ -hydrogen atoms which are removed.

Condensing agents other than aluminium chloride have been tried; a far better yield (nearly 70%) of phenanthrene has been obtained when anhydrous zinc chloride is used; the quantity of plastic byproduct is also very much reduced.

If, however, the removal of the halogen acid is carried out with the help of potassium hydroxide, no ring-closure leading to the formation of phenanthrene is observed. Alkalis therefore remove the halogen acid only from the side-chain with the formation of polymerised products (whose nature has not yet been closely investigated) if solid potassium hydroxide is used and of considerable quantity of *o*-diphenylacetylene on heating with alcoholic potash.

The *o*-phenyl- $\omega$ -halogenostyrenes therefore suffer the loss of a molecule of the halogen acid in two different ways: firstly with the help of metallic chlorides like aluminium and zinc chloride where the *ortho*-halogen atom of the second

aromatic nucleus is lost along with the terminal halogen atom of the ethylenic side-chain, leading to the formation of tricyclic aromatic hydrocarbon, phebanthrene, and secondly with the agency of caustic alkalis when the reaction is confined to the side-chain and leads either to polymerised products or to the formation of the acetylene derivatives by the removal of a molecule of the corresponding halogen acid.



This behaviour is also in agreement with the general observation that halogen derivatives of ethylenic compounds are usually not found to yield the acetylenic compounds by the loss of a molecule of halogen acid through the agency of aluminium chloride. The method adopted in the preparation of *o*-diphenylacetylene follows closely that described by Manchot (*Annalen*, 1912, 387, 283). Gilman's method (*J. Amer. Chem. Soc.*, 1922, 44, 425; "Organic Synthesis", II, p. 67) for the preparation of phenylacetylene is not found satisfactory for the preparation of *o*-diphenylacetylene. When solid potassium hydroxide is used, the final hydrocarbon obtained is undistillable and remains unidentified, although a large quantity of halogen acid is generated (90% as estimated in the form of silver halide in the aqueous extract). On prolonged heating with alcoholic potassium hydroxide a colourless oil, which can be distilled under reduced pressure, is obtained. Dilute alcoholic solution of this compound with ammoniacal silver nitrate solution yields silver acetylide corresponding with the formula  $\text{C}_6\text{H}_5\cdot\text{C}_6\text{H}_4\cdot\text{C}\equiv\text{C}\cdot\text{Ag}$  and not with  $2(\text{C}_6\text{H}_5\cdot\text{C}\equiv\text{C}\cdot\text{Ag}) + \text{Ag}_2\text{O}$  as given by Glasser (*Annalen*, 1870, 154, 157) for the corresponding silver compound of acetylene. The silver acetylide obtained from *o*-diphenylacetylene is white when freshly precipitated but becomes red on exposure to light.

## E X P E R I M E N T A L

*o*-Phenyl- $\alpha$ : $\beta$ -dibromocinnamic Acid.—To a suspension of well powdered *o*-phenylcinnamic acid (11.2 g., 1/20 mol.) in dry chloroform (112 g.) was gradually added a solution of bromine (8 g., 1/20 mol.) in dry chloroform (80 c.c.). The solution which was surrounded by cold water, was well shaken after each addition of bromine. Considerable amount of heat was generated during the absorption of bromine and the suspension went completely in solution. The solution was kept overnight when part of the *o*-phenyl- $\alpha$ : $\beta$ -dibromocinnamic acid was precipitated as heavy granules. This was filtered off and a further quantity recovered by distilling off chloroform. On crystallisation from benzene, colourless granular crystals were obtained, m.p. 171°, yield 17 g. (8%). (Found : Br, 41.23.  $C_{15}H_{22}O_2Br_2$  requires Br, 41.67 per cent).

*o*-Phenyl- $\omega$ -bromostyrene.—The above acid (13 g., 1/30 mol.) on being added to 100 c. c. of sodium carbonate solution (3.5 g., 1/30 mol.) gave a clear alkaline solution. This solution, however, soon became turbid and on standing for  $\frac{1}{2}$  hour the turbidity disappeared and an oil was produced. It was refluxed on the water-bath for an hour at the end of which the production of the oil was complete. After cooling, the oil was extracted with ether and dried overnight with anhydrous sodium sulphate. The ether was evaporated and the residue on being further distilled under reduced pressure gave an oily product, b. p. 157°/0.5 mm., yield 8.2 g. (93%). (Found : Br, 30.6.  $C_{14}H_{11}Br$  requires Br, 30.88 per cent).

*Phenanthrene (with aluminium chloride).*—Well powdered anhydrous aluminium chloride (0.27 g., 1/500 mol.) was gradually added to freshly distilled *o*-phenyl- $\omega$ -bromostyrene (5.20 g., 1/50 mol.) contained in a dry flask, fitted with an air-condenser. The flask was then placed in a water-bath whose temperature was slowly raised to boiling point. At 55° a vigorous reaction occurred suddenly and the contents darkened considerably with the evolution of a large amount of gas. Heating was continued and the flask was kept in boiling water for an hour at the end of which evolution of hydrobromic acid ceased completely. The dark mass was treated with ice-cold water and on being removed from the sides of the flask it assumed a yellow colour. It was extracted with ether and dried overnight with fused calcium chloride. The ether was distilled off and the residue on being distilled under reduced pressure gave an oil, b. p. 144°/0.5 mm., which solidified into colourless crystals on cooling. The solid on crystallisation from 70% alcohol gave shining flakes of phenanthrene, m. p. 99°, yield 1.4 g. (39%). The picrate prepared by the usual method melted at 145°. (Found : C, 59.15 ; H, 2.19. Calc. for  $C_{20}H_{13}O_7N_3$  : C, 58.97 ; H, 3.19 per cent). The regenerated phenanthrene had m.p. 100°. (Found : C, 94.47 ; H, 5.46. Calc. for  $C_{14}H_{10}$  : C, 94.39 ; H, 5.62 per cent). The identity of phenanthrene and its picrate was confirmed by mixed m.p. with a specimen of pure (Schuchardt) phenanthrene and its picrate.

*Phenanthrene (with zinc chloride).*—Well powdered anhydrous zinc chloride (2.7 g., 1/50 mol.) was gradually added to freshly distilled *o*-phenyl- $\omega$ -bromostyrene

(5.2 g., 1/50 mol.) contained in a dry flask fitted with an air-condenser. The flask was kept in an oil-bath whose temperature was gradually raised. At 175° (bath temperature) vapours of hydrogen bromide started escaping from the top of the condenser. The oil-bath was then maintained at 180° for 5 hours and the flask was well shaken at frequent intervals. After 5 hours the evolution of hydrobromic acid ceased completely and the heating was stopped. After cooling, the contents were given a similar treatment as in the previous case and shining flakes of phenanthrene (m.p. 99.5°) were obtained, yield 2.6 g (72.5%). The picrate melted at 144°. (Found: C, 59.20; H, 2.89. Calc for  $C_{20}H_{13}O_7N_3$ : C 58.97; H, 3.19 per cent). The regenerated phenanthrene melted at 100°. (Found: C, 94.49; H, 5.4. Calc for  $C_{14}H_{10}$ : C, 94.39; H, 5.62 per cent). The identity of phenanthrene and its picrate was established as in the previous case.

Similarly well powdered anhydrous zinc chloride (2.7g., 1/50 mol.) and *o*-phenyl- $\alpha$ -chlorostyrene (4.3 g., 1/50 mol.) were heated together for 5 hours at 200°. The resulting product on being treated as in the previous case produced a high yield (2.4 g., 67%) of phenanthrene. The picrate melted at 144°. (Found: C 59.18; H, 2.98. Calc. for  $C_{20}H_{13}O_7N_3$ : C, 58.97; H, 3.19 per cent). The regenerated phenanthrene melted at 100°. The identity of phenanthrene and its picrate was established in the usual manner.

*o*-Diphenylacetylene.—Freshly distilled *o*-phenyl- $\alpha$ -bromostyrene (5g., 1/52 mol.), absolute alcohol (3.1g., 1/15 mol.) and pellets of pure potassium hydroxide (3.8 g., 1/15 mol.) were taken in a dry flask fitted with a condenser. The flask was kept in an oil-bath which was gradually heated and maintained at 125° while the flask was shaken frequently. The contents were heated at this temperature for 3 hours after which no more potassium bromide appeared to separate. After cooling, ice-cold water was added and the oil produced was extracted with ether. The ethereal extract was left overnight with calcium chloride. The ether was evaporated and the residue on distillation under reduced pressure gave an oil, b. p. 137°/3 mm., not solidifying on cooling, yield 2.45 g. (71.3%). (Found: C, 94.66; H 5.31  $C_{14}H_{10}$  requires C, 94.39; H 5.62 per cent).

*Silver Compound of o*-Diphenylacetylene.—When a very dilute solution of *o*-diphenylacetylene in alcohol was mixed with an excess of an ammoniacal solution of silver nitrate, a turbidity was immediately produced and tiny bubbles of gas (hydrogen) were evolved. The mixture was well shaken and kept aside for 14 minutes, at the end of which a large amount of white precipitate deposited at the bottom. The precipitate was filtered at the pump, washed first with an ammoniacal water, then with alcohol and finally with absolute ether. It was dried to a constant weight in a vacuum desiccator and the composition determined by ignition. (Found: Ag 37.72.  $C_{14}H_9Ag$  requires Ag, 37.88 per cent).

## DETERMINATION OF MOLECULAR WEIGHT OF CARDIOTOXIN BY DIFFUSION METHOD

BY NIRMAL KUMAR SARKAR

The molecular weight of cardiotoxin (an active principle isolated from cobra venom) has been determined from its rate of diffusion through a porous diaphragm (made of alundum) and is found to be approximately 46,200. The method and the principles of calculation have also been discussed.

Various methods such as osmotic pressure, depression of the freezing point, determination of the diffusion constant, etc. have been employed to determine the molecular weights of various substances. The diffusion method has been first successfully applied by Northrop and Anson (*J. Gen. Physiol.*, 1928, 12, 543). This method has also been used by many other workers to calculate molecular weights of various biologically active substances. One of the many advantages of this method is that it can be applied even to substances which cannot be obtained in the pure state. It is extremely simple in practice and readily available. It also facilitates the determination of molecular weights of proteins such as enzymes, viruses, etc. in a concentration too low to be measured by chemical methods but can readily be determined biologically. Further, to determine the diffusion constant, it is only necessary to estimate the percentage of the substance that diffuses out.

Though the method appears to be simple and advantageous, yet the calculation of the molecular weight involves many uncertainties and assumptions which, in practice, may not be valid. Firstly, it is not known how great an error is made in making the assumption that the particle is spherical and secondly, the molecular volume calculated from the diffusion coefficient will be high, because the radius given by the Einstein's law is the radius of the hydrated molecule. Since the application of Einstein's law involves various assumptions and numerous uncertainties, there is great doubt about the actual significance of the molecular weight obtained by diffusion method; in spite of these facts it has been widely used by others. It has been applied by Northrop and Anson (*loc. cit.*) to hemoglobin, by Northrop (*J. Gen. Physiol.*, 1929-30, 13, 739) to pepsin, by Scherp (*ibid.*, 1932-33, 16, 725) to trypsin, by Kunitz and Northrop (*ibid.*, 1934-35, 18, 433) to chymotrypsinogen and chymotrypsin, by McBain, Lawson and Barks (*J. Amer. Chem. Soc.*, 1934, 56, 1021) to egg-albumin. A thorough discussion of the method may be obtained in the papers of Anson and Northrop (*J. Gen. Physiol.*, 1936-37, 20, 575) and McBain and Lin (*J. Amer. Chem. Soc.*, 1931, 53, 59).

In the light of the above discussion, it appears to us that this method will be most suitable for the determination of the molecular weight of 'cardiotoxin' for (i) it not a chemically pure substance, (ii) its concentration in the solvent

(after diffusion) is very low, and (iii) no chemical method is yet known which can estimate its concentration.

According to Einstein (*Z. Electrochem.*, 1903, 14, 235) the frictional force acting on a particle is equal to  $kT/D\eta$  ( $k$  stands for Boltzmann's constant,  $T$  for absolute temperature,  $D$  for diffusion constant and  $\eta$  for coefficient of viscosity) and is a function depending upon the size and shape of the particle. If the particle is spherical then a measurement of diffusion constant will be a direct measure of the size of the particle, as it is related to the radius of the molecule by the equation,

$$D = \frac{RT}{N} \cdot \frac{1}{6\pi r \eta} \quad (r \text{ represents the radius of the particle}$$

including the water of hydration, and  $N$ , the Avogadro's number).

When  $r$  is known, the molecular weight can be obtained from the equation,

$$M = \frac{4}{3} \pi r^3 N \rho \quad (\rho \text{ represents the density of the substance}).$$

The simplest of the many methods to determine this constant is the one which deals with the measurement of the amount diffused across a membrane in a given period of time. One advantage of this method is that the concentration gradient can be maintained almost constant over a relatively long period of time. In using this method the membrane must be standardised first, since it is quite likely that out of the whole surface area of the membrane, only a small portion may be available for the purpose and also of the fact that the dimensions of the pores are not known. The membrane is calibrated by measuring the rate of diffusion of a substance, whose diffusion coefficient is known.

When a more dilute solution ( $c_2$ ) is separated by means of a porous membrane from the other ( $c_1$ ), then the quantity ( $Q$ ) of the substance diffusing in a given time ( $t$ ) is given by

$$Q = D \cdot A \cdot t \frac{c_1 - c_2}{L} \quad \dots \quad \dots \quad (1)$$

$$\text{or } D = \frac{L}{At} \cdot \frac{Q}{c_1 - c_2} \quad \dots \quad \dots \quad (2)$$

( $L$  represents the distance through which the solute diffuses). If the experimental condition is so arranged that the more dilute solution stands for the pure solvent, then the equation (2) is further simplified to

$$D = \frac{L}{A} \cdot \frac{Q}{tc_1} \quad \dots \quad \dots \quad (3)$$

Since the concentration is expressed as the quantity per unit volume, the same unit is also used to express the quantity that diffuses out across the membrane. If the time is expressed in days, and lengths in cm., then the equation (3) becomes

$$D = \frac{L \text{ cm.}}{A \text{ cm}^2} \cdot \frac{Q \text{ units}}{t_{\text{day}} \frac{Q_1 \text{ units}}{\text{cm}^3}} = \frac{LQ \text{ cm}^2}{At_{\text{day}} Q_1} \quad \dots \quad \dots \quad (4)$$

(where  $Q_1$  represents the number of units present in unit volume of the concentrated solution). If the quantity present per unit volume of the concentrated solution is taken as the unit, i.e.,  $Q = 1$ , and the amount diffused is also expressed in this unit (i.e. as the number of c. c. of the concentrated solution containing the quantity diffused), then the above equation (4) is further simplified to

$$D = \frac{L \cdot Q_{\text{c. c. cm}^2}}{A t_{\text{day}}} = K \cdot \frac{Q_{\text{c. c. cm}^2}}{t_{\text{day}}} \quad \dots \quad (5)$$

(where the ratio of  $L/A$  is called membrane constant and denoted by  $K$ ;  $Q_{\text{c. c.}}$  is the number of c. c. of the concentrated solution containing the amount of the substance diffused in time  $t$ , expressed in days).

### EXPERIMENTAL

The arrangement used for the measurement of the rate of diffusion and the cell are similar to those used by De (*J. Indian Chem. Soc.*, 1944, 21, 308) excepting that the apparatus was placed in a refrigerator at  $5^\circ$  instead of the water-bath at  $7^\circ$  used by De.

*Standardisation of the Membrane.*—The ratio of the thickness of the membrane to its effective area is the membrane constant,  $K$ . It was calculated from the experimental results obtained by allowing standard solutions of NaCl (the diffusion coefficient of which is known) to diffuse through the membrane for a given period of time at a temperature of  $5^\circ$ . Then the membrane constant  $K$  was calculated

from the equation  $K = \frac{D t_{\text{day}}}{Q_{\text{c. c.}}}$ . Results appear in Table I.

TABLE I\*

<i>Determination of the membrane constant (K) at <math>5^\circ</math>.</i>							
Time.	Vol. of NaCl diffused out.	$Q$ per day (Average).	$K_1$ .	Time.	Vol. of NaCl diffused out.	$Q$ per day (Average).	$K_1$ .
	2N-NaCl.				1N-NaCl.		
3 hrs.	0.53 c. c.			3 hrs.	0.56 c.c.		
6	1.15	4.86 c.c.	0.165	6	1.16	4.86 c.c.	
12	2.18			12	2.18		0.165

*Determination of Diffusion Constant of Cardiotoxin.*—Purified cardiotoxin, freed from salts by dialysis, was used for the determination of its diffusion coefficient. For this purpose a 2% and a 4% solution of cardiotoxin were diluted separately with an equal volume of Ringer of pH 7.4 to give the final concentrations of the solution to 1% and 2% respectively. The same solvent (30 c. c.) in which the cardiotoxin was dissolved and of the same hydrogen-ion concentration was placed in the beaker. The diffusion cell with its contents was then suspended in the beaker and the solute was allowed to diffuse for a definite length of time. The whole arrangement was placed inside another beaker of larger dimension, kept inside a refrigerator at  $5^\circ$ . The amount diffusing out in the time allowed for the purpose, was quantitatively removed and its cardiac activity was determined. From this, the total amount of

\* Diffusion coefficient for 2N-NaCl and 1N-NaCl at  $5^\circ$  is  $0.72 \text{ cm}^2$  per day extrapolated from Ohlm's data (*Z. physikal. Chem.*, 1910, 70, 378).

cardiotoxin (in c. c.) diffused was then calculated. The density of cardiotoxin (mass per unit volume) was next determined by the displacement of xylene at 5°. Results are presented in Table II.

TABLE II  
*Diffusion coefficient of cardiotoxin at 5°.*

Cardiotoxin = 1.0%				Cardiotoxin = 2.0%			
Time.	Amount diffused in c.c.	cm <sup>2</sup> /day ( <i>Q</i> c. c.).	Average.	Time.	Amount diffused in c.c.	cm <sup>2</sup> /day ( <i>Q</i> c. c.).	Average.
2 days	0.576	0.288		2 days.	0.582	0.291	
2	0.554	0.277	0.288	2	0.548	0.274	0.288
2	0.593	0.296		2	0.600	0.300	

The diffusion coefficient of cardiotoxin can therefore be calculated by substituting the values of *K* and *Q* c. c. in the equation (5)

$$D = \frac{K \cdot Q_{c.c.}}{t_{day}} = \frac{0.165 \times 0.288}{1.0} = 0.0475 \text{ cm}^2 \text{ per day.}$$

$$\begin{aligned} \text{Now, } D &= \frac{R T}{N} \cdot \frac{1}{6\pi r \eta} \\ &= \frac{1.33 \times 10^{-13}}{r} \frac{\text{erg. deg. mole. cm}^3}{\text{erg. deg. mole. cm. sec.}} \\ &= \frac{1.33 \times 10^{-13}}{r} \frac{\text{cm}^2}{\text{sec.}} \\ &= \frac{1.148 \times 10^{-8}}{r} \frac{\text{cm}^2}{\text{day}} \\ r &= \frac{1.148 \times 10^{-8}}{D} \\ &= \frac{1.148 \times 10^{-8}}{0.00475} \text{ cm.} = 2.41 \times 10^{-7} \text{ cm.} \end{aligned}$$

$$\begin{aligned} \text{Now, } M &= \frac{4}{3} \pi r^3 \rho N (\rho = \text{sp gr. of cardiotoxin g. cm}^3) \\ &= 25.4 \times 10^{23} \times 1.3 \times r^3 \\ &= 33.02 \times 10^{23} \times 13.995 \times 10^{-21} \\ &= 46,200 \text{ (approx.).} \end{aligned}$$

Thus the molecular weight of cardiotoxin comes to be approximately 46,200.

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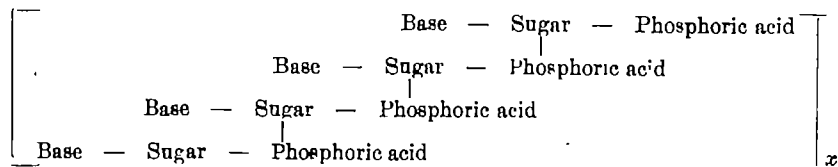
# STUDIES ON YEAST NUCLEIC ACID. PART I. DEPENDENCE OF PHYSICAL PROPERTIES OF SOLUTIONS OF THE ACID ON CONCENTRATION

BY S. N. MUKHERJEE AND N. K. SARKAR

Hydrogen-ion activity, specific conductivity and cataphoretic velocity have been studied at different concentrations of the yeast nucleic acid solution. Results indicate a progressive aggregate formation in this system proceeding from quite high dilutions. A study of extinction coefficient at different concentrations also corroborates the above inference to a considerable degree.

Nucleic acids are believed to be composed of phosphoric acid, one kind of sugar and four qualitatively different but quantitatively equivalent amounts of nitrogenous bases. When yeast nucleic acid is subjected to the action of alkali, four separate components may be readily isolated, each, referred to as the nucleotide, contains one molecule of sugar, one of phosphoric acid and one of the nitrogenous base (Levene and Bass, "Nucleic Acids", N. Y., 1931; Jones, "Nucleic Acids", N. Y. and London, 1920). The nucleotide may be represented in the most general way as nitrogenous base-sugar-phosphoric acid, wherein one terminal position is occupied by the base and the other by the phosphoric acid (Miescher, "Die histochemischen und physiologischen Arbeiten", 1897, Vol. II). This terminal base and the phosphoric acid can be obtained by hydrolysis of the nucleotide by acids and enzymes respectively (Levene and Bass, *loc. cit.*).

Regarding the number of nucleotide molecules present in a molecule of yeast nucleic acid, the question has been attacked from the point of view of the basicity of the acid by titration of its aqueous solution with a base. Extensive work has shown the acid to be tetrabasic below pH 10 (Makino, *Z. physikal. Chem.*, 1935, 236, 201; Gulland, *J. Chem. Soc.*, 1938, 1722; Allen and Eiler, *J. Biol. Chem.*, 1941, 137, 757; Hammarsten, *Biochem. Z.*, 1924, 144, 383; Levene and Bass, *loc. cit.*). The works of Bredereck and co-workers (*Ber.*, 1928, 71, 2389; 1939, 72, 1429) as well of Loring and Carpenter (*J. Biol. Chem.*, 1943, 150, 381) have further established that the four nucleotides are probably bound together through phosphate ester linkages between adjacent nucleotides. The probable representation of the structure has been as follows:



The principal drawback of such a structure is that it should give five ionisable hydrogen atoms, while experimental evidence referred to above indicates the presence of four such atoms only. An attempt to remove this discrepancy has

been made by a consideration of the polymerisation of the acid which has been corroborated by the observed values of the molecular weights of the sodium salt of the thymonucleic acid in different preparations ranging from  $5 \times 10^5$  to  $1 \times 10^6$  (Signor, Caspersson and Hammarsten, *Nature*, 1938, 141, 122; Tennen and Vilbrandt, *J. Amer. Chem. Soc.*, 1943, 65, 424, 1806) and of the yeast nucleic acid of about  $2 \times 10^4$  (Loring, *J. Biol. Chem.*, 1939, 135, 128; *Proc. Amer. Chem. Soc. Biochem.*, 1939, 61; Kunitz, *J. Gen. Physiol.*, 1940, 24, 15). Miescher (*loc. cit.*) also noted the high molecular weight of the acid. The nucleic acids thus are substances with high molecular weight and it appears that the tetranucleotide structure is many times present within the actual molecule. The linkage between the tetranucleotide in such molecules might well involve the fifth hydrogen atom of the tetranucleotide. Hence as more and more tetranucleotides polymerise to form the large molecule, the basicity of the latter approaches more and more to the observed value of four per tetranucleotide unit. The reverse phenomenon has been observed in the case of yeast nucleic acid which, when broken up, begins to exhibit the presence of the fifth H. atom (Allen and Eiler, *loc. cit.*)

Evidently the principal physicochemical work that has been done on the nucleic acid mainly refers to the elucidation of its structure. The nucleic acid in aqueous solution behaves as an electrolytic colloid having considerable electrical conductance comparable to that of electrolytes. Hammarsten's observations (*loc. cit.*) first of all brought out that the osmotic pressure of thymonucleic acid solutions was very much less than that calculated from its electrical conductivity, although it agreed quite well with the values from freezing point measurements. Hammarsten referred this anomaly to the size of the ions into which the nucleic acid ionised; the smaller ions being lost osmotically in the sphere of attraction of ions of bigger size and of opposite sign. By using ions of comparable dimensions he could show that the anomaly disappeared and the behaviour came back to normal.

The osmotic anomaly observed by Donnan and Harris (*J. Chem. Soc.*, 1911, 99, 1534) in the Congo-red solutions was explained by the authors as due to the non-diffusibility of bigger ions which kept the smaller ions of opposite charge bound by electrostatic attraction.

A more rational explanation was suggested by Linderstrom-Lang (*Compt. rend. trav. Lab. Carlberg*, 1926, 16, No. 16; *vide* also the discussion by McBain, *J. Amer. Chem. Soc.*, 1928, 50, 1636) from thermodynamic grounds suggesting that some type of aggregate formation was proceeding in the system which was directly responsible for the anomaly referred to above. Van Rysselberghe (*J. Phys. Chem.*, 1934, 38, 646) has discussed this aspect from the Debye-Hückel interionic attraction theory on the assumption that nucleic acid molecules polymerise to form micelles of larger dimensions. McBain and Betz (*loc. cit.*) attempted an explanation from the view-point of the existence and formation of neutral micelles above certain concentrations in these systems of colloidal electrolytes.

Thus, as evident from the above, aggregate formation has been held responsible for the high molecular weight of the acid, the occurrence of the tetrabasicity and also for the suggested structure of the acid. Formation of aggregates in aqueous solution has also been believed to be at the root of osmotic anomaly observed by Hammarsten, although different workers have looked at the problem from different angles of vision.

The works in connection with aggregate formation in solution have been carried out mostly by observing how physical properties of the solution change with its concentration and plotting the observation with concentration graphically. A break or kink in the curve has been regarded as a positive evidence (Hartley, *Kolloid Z.*, 1939, **88**, 22). Any physical property can be chosen, but the two properties which have been generally used have been the specific volume (Grindley and Bury, *J. Chem. Soc.*, 1929, 679) and the equivalent conductivity, of which again the latter has been regarded as the more important (Hartley, *ibid.*, 1938, 1968; *J. Amer. Chem. Soc.*, 1936, **58**, 2347; Lottermoser and Frotscher, *Koll.-chem. Beih.*, 1937, **15**, 303; Lottermoser and Püschel, *Kolloid Z.*, 1933, **63**, 175; McBain and Salmon, *J. Amer. Chem. Soc.*, 1920, **42**, 426; McBain, Laing and Titley, *J. Chem. Soc.*, 1919, **115**, 1279).

In the study on the variation of equivalent conductivity with concentration, there is a fundamental agreement in the observations of the different workers who worked with different systems. The  $\Lambda - \sqrt{c}$  curve, with the help of which these observations have been generally represented, shows a sudden kink at low concentrations. The position and occurrence of this inflexion point (critical concentration) have been correlated to the number of carbon atoms in the case of long chain compounds (*cf.* Lottermoser and co-workers, *loc. cit.*). At higher concentrations the  $\Lambda - \sqrt{c}$  curve reaches a minimum beyond which there is a tendency to increase as the concentration becomes higher.

All the workers in this line agree that at very low concentration the colloidal electrolytes in aqueous solution remain ionised and the ions are monomeric (as opposed to aggregated micelles). At the inflexion point aggregate formation starts which proceeds up to higher concentrations. It is in point of the nature of these aggregates that divergence of opinion amongst different workers really arises. McBain (*loc. cit.*) believes that these aggregated micelles are neutral molecules, which according to Lottermoser and co-workers (*loc. cit.*) acquire surface charge by ionisation at the surface or by adsorption of ions from the solution and thus exhibit cataphoretic motion. Hartley (*loc. cit.*) believes in only one type of micelles, viz., the ionic micelles which by interionic attraction build up an ionic atmosphere and keep an increasing number of counter-ions bound in this atmosphere. The increase occurring in the  $\Lambda - \sqrt{c}$  curve beyond the point of minimum  $\Lambda$  has been explained by McBain as due to the formation of ionic micelles in this region, while Hartley believes this to be due to the disruption of the ionic atmosphere whereby a number of counter-ions are released thus increasing the conductivity of the solution.

Lottermoser has, however, discussed these view-points critically (Lottermoser and Frotscher, *loc. cit.*). No final conclusions have as yet been reached.

Thus although the high molecular weights of the nucleic acids have been explained on the assumption of polymerisation or association, and although the nature of the variation of equivalent conductivity ( $\Delta$ ) with concentration has also found explanation on assumption of aggregate formation in aqueous solution of the acid, no attempt has been made to ascertain as to whether this aggregation is of similar nature to that occurring in the case of well known colloidal electrolytes, like salts of long chain fatty acids or of long chain sulphonic acids, etc., nor has any attempt been made to settle whether this aggregation process is sudden and starts abruptly for the critical concentration or whether it proceeds at all concentrations without showing a break anywhere in the  $\Delta - \sqrt{c}$  curve.

The object of the present investigation is to open the question again on the same lines as in the case of typical colloidal electrolytes viz. by studying the physical properties of the aqueous solution of the acid and noting how they change with concentration of the solution. For this reason a variety of physical properties has been studied and their variations noted with concentration. The nature of the  $p - f(c)$  curve is expected to furnish the useful informations on these points where  $p$  is the value of any physical property at a concentration  $c$ , and  $f(c)$  is any function of this concentration.

## EXPERIMENTAL

*Preparation of the Sol.*—Yeast nucleic acid (B. D. H.) was purified essentially by the method of Bungenberg de Jong (*Koll.-chem. Beih.*, 1938, 47, 254) by dissolving the acid (1.5g.) in the least quantity of *N*-ammonium hydroxide solution and subsequently precipitating the acid by excess of 3*N*-acetic acid. Three repetitions of the process were found essential to reduce the ash content from 1.2% to 0.08%. The residue after washing with alcohol, free from acetic acid, and drying at room temperature was tested for its purity (*cf.* Hammersten, *loc. cit.*). Chlorides, phosphates and proteins were found to be absent. Further, moisture, phosphorus, nitrogen and ash contents have been estimated, results of which are presented below. The figures represent the mean value of two determinations in the cases of moisture and the ash content, and three determinations in the cases of nitrogen and phosphorus.

TABLE I

	Sample I.	Sample II.	Sample III.
Moisture (105° for 12 hrs.)	11.08%	10.68	11.29
Phosphorus (by conversion into phosphate and precipitation by $\text{NH}_4$ -molybdate)	8.70	8.58	8.60
Nitrogen (Kjeldahl's method)	14.80	14.69	14.73
Ash content (by incineration)	0.08	0.09	0.11
Nitrogen to phosphorus ratio (N/P)	1.70	1.71	1.71

Evidently the three different samples prepared by the same method yielded analytical results almost identical. The N/P ratio is almost constant in the three cases which according to Hammersten (*loc cit*) should be the guiding factor in the estimation of purity of samples.

Solutions were prepared by carefully weighing out 0.25 g. of the acid per 100 c.c. of conductivity water (sp. conductivity =  $1.15 \times 10^{-8}$  mho). Before introducing the acid the conductivity water was sterilised by prolonged boiling and cooled carefully avoiding contamination from outside. The acid was then introduced and the mixture shaken in a mechanical shaker for 3 to 4 hours when the solid acid became dispersed. The solution, when viewed under the ultramicroscope, exhibited the Tyndall phenomenon and hence was of colloidal character. On keeping the sol overnight a part of the solid settled down, the remaining part formed a fairly stable suspension and did not settle easily. The suspension which was slightly yellowish was preserved under a layer of pure toluene.

*Methods of Measurement.*—Present investigation has been principally confined to determination of the hydrogen-ion activity, specific conductivity of the suspension and the cataphoretic velocity of the colloidal particles at different concentrations of the suspension. Measurements were all carried out at  $35^\circ \pm 0.1$  except where stated otherwise.

Potentiometric measurements were carried out with hydrogen electrode against a saturated calomel half element. Pt-electrodes for potentiometric measurements were freshly prepared every day after removing the grey deposit at the end of each day's work and a fresh deposit was formed by replatinisation. The electrode was washed free from acid by the usual method (*cf.* Mukherjee *et al.*, *J. Agric. Sci.*, 1936, 6, 517).

Cataphoretic velocity was measured by the microscopic method in a cell of the Freundlich and Abramson type at the room temperature. Readings were always taken at 0.21 depth of the cell. The potential gradient was measured by the help of Ohm's law from a knowledge of the current flowing through the cell and the specific conductivity of the suspension.

Concentrations of the suspension were determined by precipitating the acid with alcohol and washing the precipitate thoroughly with alcohol-water mixture. The acid so obtained was dried at room temperature ( $30^\circ$ ) and weighed. Concentration was finally calculated after making allowance for the moisture content of the specimens which were found to contain about 11% of moisture approximately.

*Ageing and Reproducibility.*—Four different samples of nucleic acid solutions (vide Table II) were studied to investigate into the effect of ageing so far as the specific conductivity, hydrogen-ion activity and cataphoretic velocity were concerned\*.

\* These properties were studied everyday as a matter of routine work. Data for all the days of observation have not been presented in the table for economy of space. Those for 1st, 5th, 10th, 15th and 20th days have been shown.

TABLE II

No. of day.	Sample I (conc. 1g./litre)			Sample II (conc. 1g /litre)		
	Sp. condy.	pH.	C.V.	Sp. condy.	pH.	C.V.
1	$6.01 \times 10^{-4}$	3.00	$5.82 \times 10^{-4}$	$6.12 \times 10^{-4}$	2.98	$5.22 \times 10^{-4}$
5	6.00	3.01	5.82	6.10	2.98	5.25
10	6.03	3.00	5.80	6.13	2.94	5.15
15	6.05	3.02	5.50	6.09	2.96	5.80
20	6.15	3.10	6.21	6.25	3.15	7.20
25	6.50	3.23	—	6.38	3.29	—
Sample III (conc. 1.08g./litre)				Sample IV (conc. 0.098g./litre)		
1	6.09	2.97	5.18	6.00	3.02	5.05
5	6.10	2.95	5.11	6.05	3.00	5.07
10	6.07	2.92	5.10	6.02	2.99	5.01
15	6.08	2.96	5.20	6.02	3.01	5.01
20	6.21	3.10	5.90	6.20	3.25	5.93
25	6.40	3.27	—	6.32	3.40	—

It is also clear from the table that for the first 15 days there was no indication of any change in the properties studied after which they were found to undergo change with the progress of time. After about a month's time growth of moulds could be detected inside the sol. For this reason no experiments were done in this investigation and in all subsequent work with any suspension preserved for more than a fortnight.

Different samples of nucleic acid suspensions were used in course of these experiments since the same suspension could not be used 15 days after its preparation. It was therefore thought necessary to ascertain whether different samples of the nucleic acid sol could have comparable properties. From Table II again it is evident that the reproducibility in four different samples is fairly satisfactory so far as pH, specific conductivity and cataphoretic speeds are concerned provided the concentrations are equal.

*Attainment of Equilibrium.*—In potentiometric and conductometric titrations (recorded in this investigation) bases were always added at intervals of 15 to 20 minutes. Attainment of necessary equilibrium within this short time has been ascertained from an agreement (up to the third decimal place) between two potential or resistance measurements. The equilibrium was further examined by allowing the nucleic acid solution to remain in contact with different amounts of NaOH (as used in potentiometric and conductometric titrations) in a series of Jena bottles for about 24 hours. The pH value of the content of each bottle was measured separately and compared with the corresponding data of actual titrations where readings were taken 15 to 20 minutes after addition of each instalment of the base (Table III).

TABLE III

*Yeast nucleic acid solution.*Conc. = 1.089 g./litre. Vol. taken = 10 c.c. Temp. =  $35^{\circ} \pm 0.1$ .

N-NaOH added.	pH (obs.) in bottles after 24 hours.	pH in actual titration after 15 min.	N-NaOH added.	pH (obs.) in bottles after 24 hrs.	pH in actual titration after 15 min.
$17.7 \times 10^{-4}$	3.62	3.60	$59.0 \times 10^{-4}$	7.15	7.17
29.5	4.40	4.40	73.6	9.10	9.13
44.3	5.75	5.80	103.3	10.22	10.20

*Hydrogen-ion Activity.*—Results for hydrogen-ion activity ( $a_H$ ) for different concentrations of the acid suspension have been presented in Table IV.

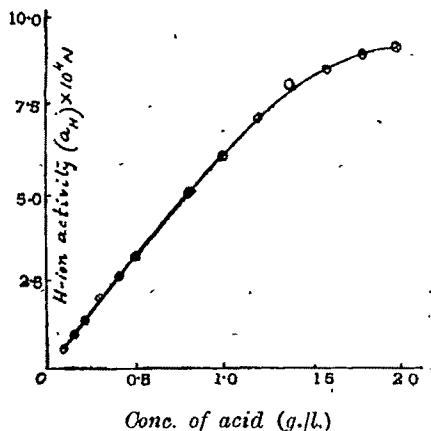
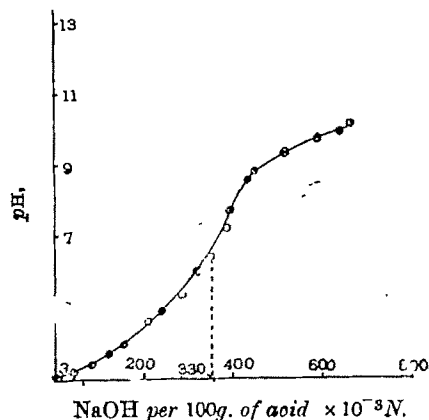
TABLE IV

*Yeast nucleic acid suspension (A)*Temp. =  $35^{\circ} \pm 0.1^{\circ}$ 

Conc.*	pH.	Free acidity ( $a_H \times 10^4 N$ ).	Total acidity ( $c_H \times 10^4 N$ ).	$a_H/c_H$ ratio ( $f$ ).	Conc.*	pH.	Free acidity ( $a_H \times 10^4 N$ ).	Total acidity ( $c_H \times 10^4 N$ ).	$a_H/c_H$ ratio ( $f$ ).
0.08	4.30	0.60	2.52	0.199	1.00	3.25	5.92	31.50	0.188
0.15	3.81	0.94	4.73	0.199	1.20	3.16	7.00	37.80	0.185
0.20	3.76	1.25	6.30	0.200	1.40	3.11	7.85	44.10	0.178
0.28	3.70	1.79	8.82	0.202	1.60	3.08	8.25	50.40	0.164
0.40	3.59	2.58	12.80	0.203	1.80	3.05	8.70	56.62	0.154
0.50	3.50	3.08	15.75	0.196	2.00	3.00	9.00	63.00	0.143
0.80	3.85	4.87	25.20	0.192					

\* Conc. expressed in g. per litre.

Activity of H-ions have been calculated from pH values and presented in columns 3 and 8. The variations of  $a_H$  with concentration have been shown in Fig. 1. The curve is steeper at lower concentrations but the slope decreases at a concentration of approximately 1.4 g. per litre. There is, however, no sharp break in the curve.

FIG. 1.  
 *$a_H$ -c curve.*FIG. 2  
*Potentiometric titration curve.*

In columns 4 and 9 of the table the total titratable acidity ( $c_H$ ) as obtained by potentiometric titration of the acid with NaOH at different concentrations have been presented. A complete potentiometric titration curve at one concentration has been shown in Fig. 2. The end-points for the titrations were determined from the steep inflexions which were found to occur at  $p_H$  varying from 7.1 to 7.5. It appears from the  $c_H$  values that they vary linearly with concentration. This means that the total acidity per 100 g. of the acid remains constant at all concentrations to a value of approximately 325 m.e per 100 g. of the acid.

The ratio of free to total acidity at different dilutions has been calculated and presented in columns 5 and 10 of Table IV. A graphical representation of these data appear in Fig. 3. The curve obviously shows a slight rise at low concentrations, followed by a steep drop at 0.4 g./litre. A second break in the

FIG. 3.  
 $\alpha_H/c_H - c$  curve.

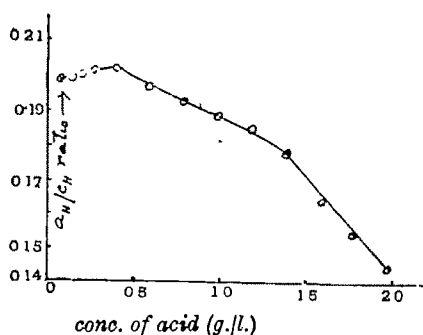
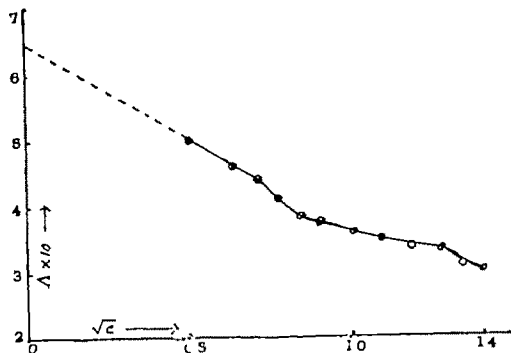


FIG. 4.  
 $\Lambda - \sqrt{c}$  curve.



curve is also evident at a higher concentration of 1.4 g./litre. The curve thus simulates, to a certain extent, those obtained by Lottermoser and Püschel (*loc. cit.*) in the case of Ag-ion activity in the Ag-salts of alkyl sulphonic acids and also those obtained by Lottermoser and Frötscher (*Koll.-chem. Beih.*, 1937, 45, 303) for the Cl' activity of different alkyl pyridinium chlorides. A rise (though small) in the curve at low concentrations was also observed by these authors for Ag-ions in the Ag-salts of alkyl sulphonic acids having 12 and 14 atoms of carbon in the chain and for Cl ions in the octadecylpyridinium chloride.

*Specific and Equivalent Conductance.*—Results for variation of conductance with concentration of the solution have been presented in Table V.

TABLE V

Conc.*	$\sqrt{c}$	Sp. condy. ( $\kappa$ ) $\times 10^4$ mho	Sp. condy. calc. from $\alpha_H \times 10^4$	Equiv. condy. $\times 10^4$ in mho.	Conc.*	$\sqrt{c}$	Sp. condy. ( $\kappa$ ) $\times 10^4$ mho.	Sp. condy. calc. from $\alpha_H \times 10^4$	Equiv. condy. $\times 10^4$ in mho.
0.25	0.50	1.25	0.70	5.0	1.00	1.00	3.60	2.37	3.85
0.40	0.63	1.80	1.03	4.61	1.20	1.09	4.15	2.80	3.60
0.50	0.71	2.20	1.28	4.40	1.40	1.18	4.70	3.14	3.35
0.60	0.77	2.25	1.40	4.10	1.60	1.24	5.65	3.48	3.10
0.70	0.84	2.73	1.60	3.90	2.00	1.40	6.00	3.60	3.00
0.80	0.89	3.10	1.94	3.85					

\* Conc. expressed in g./litre.



Columns 3 and 7 show the variation of specific conductance ( $\kappa$ ) with concentration. By drawing the  $\kappa - c$  curve from these data (the curve not presented here) it becomes evident that there is no point of special interest and the run of the curve is of the type found with most of the common electrolytes.

Equivalent weight of this acid cannot be definitely ascertained because the total acidity has been found to vary with the nature of the base used for titrating this acid, although such variations have been quite small in comparison with some soil colloids (*e. g.* hydrogen clays) investigated in these laboratories (unpublished work).

Equivalent conductivity cannot therefore be calculated in this case. We can, however, define a quantity, viz., conductivity per gram of the acid ( $\Delta$ ) which is proportional to the equivalent conductivity.

$$\Delta = \frac{\kappa \times 1000}{c}$$

where  $c$  stands for the number of grams of the acid per litre of the solution.

When these  $\Delta$  values (columns 5 & 10, Table V) are plotted against  $\sqrt{c}$ , we should normally expect to get a straight line according to Onsager's relation,

$$\Delta_c = \Delta_\infty - k\sqrt{c}$$

where the terms have their usual significance and  $k$  is a constant giving the slope of the straight line. Graphical representation of  $\Delta$  against  $\sqrt{c}$  is shown in Fig. 4. The graph presents the following features :

(i) Beyond a certain concentration (0.49 g./l.)  $\Delta$  appears to diminish more rapidly with  $\sqrt{c}$ . The curve thus presents a break in this region but the break is not so sharp as those obtained with many colloidal electrolytes by Hartley (*loc. cit.*), McBain (*loc. cit.*) and Lottermoser (*loc. cit.*).

(ii)  $\Delta$  does not appear to pass through a minimum but shows a second break near about a concentration of 1.4 g./l. beyond which a slightly steeper run is observed.

(iii) The curve, extrapolated to zero concentration, gives low values for equivalent conductance. The value obtained by straight line extrapolation gives a value of  $\Delta$  which is much lower than that obtained from the activity of hydrogen ions alone

(iv) Columns 4 and 8 of Table V give values of specific conductance as calculated from the  $a_H$  at the corresponding concentrations as determined by potentiometric measurement of  $p_H$ . Calculations have been carried out on the assumption that the equivalent conductivity of H ions at 35° is 400 mho (*cf.* Glassstone, "Electrochemistry of Solutions", 1937, p. 72; Int. Crit. Tables, 1929, VI, 259) and that it is not influenced by presence of other ions in solution (*cf.* independent migration of ions). The calculated values, as will be evident from the table, are in all cases lower than the observed values and it is of interest to note that the discrepancy increases with increasing concentration. This aspect will be discussed in a subsequent section.

*Cataphoretic Velocity.*—Cataphoretic velocities at different concentrations are given in Table VI and graphically represented in Fig 5.

TABLE VI  
*Yeast nucleic acid solution.*

Temp  $-30^{\circ}$ .

Conc (g./l.)	C. v. for sol A.	C. v. for sol B.	Conc. (g./l.)	C. v. for sol A.	C. v. for sol B.
0.25	$1.6 \times 10^{-4}$	—	1.20	$7.8 \times 10^{-4}$	$6.95 \times 10^{-4}$
0.40	2.0	—	1.40	7.2	6.61
0.80	4.6	$5.8 \times 10^{-4}$	1.60	6.7	6.05
0.90	5.3	6.31	1.80	6.2	5.83
1.00	6.0	7.22	2.00	5.6	5.22

It is evident that c. v. at first increases with concentration, passes through a maximum and then decreases a little slowly. It has been observed in this laboratory (Mukherjee, Chaudhury and Ghosh, *Trans. Nat. Inst. Sci. India*, 1935, 1, 47) that aggregation during coagulation is often associated with increase in cataphoretic velocity. This suggests that during the rise of cataphoretic velocity probably aggregation of the anions of nucleic acid takes place. Measurements in

FIG. 5.  
C.V.-c curve.

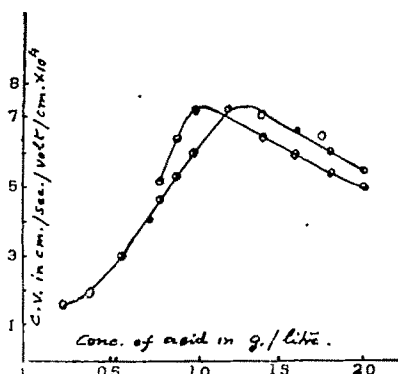
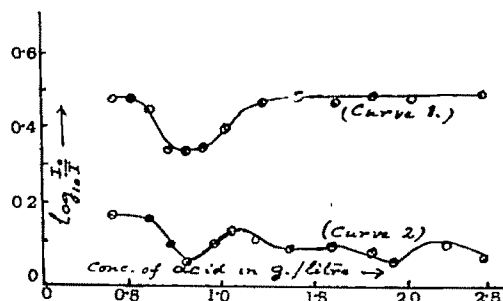


FIG. 6.  
 $\zeta$ -c curves.



this case begin from a concentration of 0.25 g. of the acid per litre. Lower concentrations could not, however, be studied since in these cases the particles were not distinctly visible under the microscope. When, however, the concentration was raised, higher than 1 g. per litre, particles could be vividly seen and some of them were found to possess greater velocity than the others. The size of such particles, as far as could be judged under the microscope, appeared to be larger in some cases. To confirm this point further, another sample of the nucleic acid sol (sol B) was similarly studied for its cataphoretic velocity at different concentrations.

The only inference that could be drawn from these measurements is that probably there is some type of aggregate formation in the nucleic acid sols. But whether this process is a progressive one from low concentrations or whether it begins at any critical concentration and ends some where else, could not be ascertained definitely.

*Extinction Coefficient.*—Kruyt and co-workers (*Kolloid Z.*, 1936, 75, 318) observed that Beer's law holds good for gold and selenium sols. Any deviation from Beer's law has been suggested by them to be due to some kind of internal change taking place in the colloid. Various types of deviations from Beer's law have been observed by different workers and it is not *a priori* possible to predict from theoretical considerations only whether any deviation from Beer's law should be due to change in the total number of particles or due to some other secondary phenomena.

Extinction coefficient has been calculated from the relation,

$$\log e \frac{I_0}{I} = \epsilon c l$$

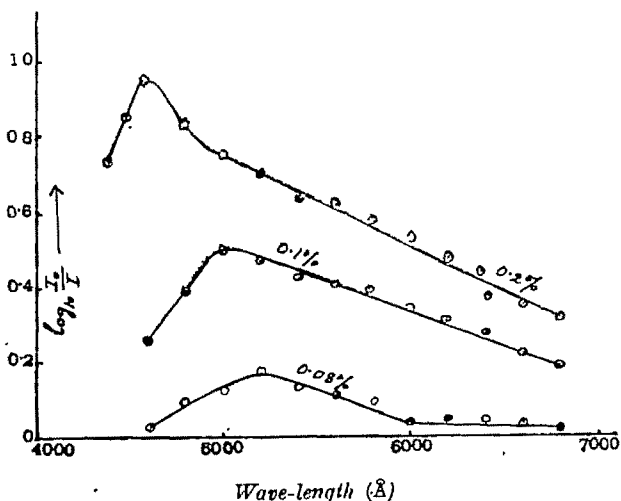
where  $\epsilon$  stands for extinction coefficient per unit concentration,  $l$  for the stratum thickness of the absorption cell and  $c$  for the concentration of the acid in g. per litre.  $\epsilon$  therefore in the present case refers to extinction coefficient per g. of the acid per litre of the solution.  $I_0$  represents the intensity of the incident radiation and  $I$ , that after transmission through the solution. By making necessary transformations, the relation becomes

$$2.303 \log_{10} \frac{I_0}{I} = \epsilon c l$$

The value of  $\log_{10} \frac{I_0}{I}$  is therefore a measure of  $\epsilon$  at a constant concentration  $c$  and at constant value of  $l$ . In these experiments an absorption cell of 1 cm. in thickness was always used.

FIG 7.

*Absorption curves at diff. temp.*



Before undertaking the actual measurement Lambert's law was verified in this system as a check on experimental accuracy. Results were found satisfactory.

Next the wave-length of maximum absorption was determined. Results are shown in Fig. 7. The curves extend from a wave-length of 4500Å to 6500Å beyond which visibility was extremely reduced.

Since maximum extinction coefficient means a maximum of absorption, from the figure the region of maximum appears to vary with the concentration, the displacement being towards the high frequency side with increase in concentration. In subsequent measurements to examine the effect of concentration on  $\epsilon$ , measurements were made at a wave-length of 4500Å only.

Fig. 6 (curve 1) presents the variation of  $\epsilon$  with concentration. The curve passes through a minimum which occurs at a concentration of approximately 0.4 g. per litre. The results in themselves are difficult to interpret. An elucidation was, however, attempted by examining the change in extinction coefficient ( $\epsilon$ ) during slow coagulation. For this reason a small quantity of  $\text{Ba}(\text{OH})_2$  was added to the solution of the acid and the change in extinction coefficient noted with time. The result is shown in Fig. 6 (curve 2) in which a concentration of 2 g./litre was used. The units chosen have been arbitrary in order to accommodate the curve in the same figure for purposes of comparison. The value of  $\epsilon$  (as evident from the figure) decreases with time, passes through a minimum and then fluctuates about some mean value as inferred from the shape of the curve.

## DISCUSSION

From the foregoing results it is evident that the  $a_H/c_H - c$  and  $\Lambda - \sqrt{c}$  curves both show two breaks at about the same concentrations viz. 0.4 g./litre and 1.4 g./litre. The  $c_v - c$  curve shows only one maximum at a concentration of about 1.4 g./litre. Moreover, the  $\Lambda - \sqrt{c}$  and  $c_v - c$  curves show close resemblance with similar curves obtained in the cases of some typical colloidal electrolytes (Pauli and Valko, "Electrochemie der Kolloide", 1929; Hartley, *Kolloid Z.*, 1939, 88, 22; Lottermoser and Püschel, *ibid.*, 1933, 63, 175).

The  $a_H/c_H$  (Fig. 3) ratio, which serves as a measure of the free acidity per g. of the acid, has low values at all concentrations and possesses a tendency to decrease with increase in concentration at higher concentration regions. Hartley (*loc. cit.*) explained these low values of the activity coefficients of the counter-ions in solutions of long chain alkyl halides, which are well known colloidal electrolytes, undergoing aggregation in solution. He assumed that a part of the counter-ions remained associated with the micelles formed by aggregation and a part only could form the ion-atmosphere and calculated the effect of the latter by the application of Debye-Hückel's theory by taking into account the size of the micelles, the charge on their surface after making allowance for the diminution brought about by that part of the counter-ions which remained firmly held up with the micelle. In a particular case, his calculations show that for a definite concentration, ( $N/100$ ) if

the negatively charged long-chain alkyl ion remains as a single monomer having point dimension, the value of the activity coefficient comes up to 0.96 ; while if they aggregate into a micelle of  $24\text{\AA}$  diameter with 25 units of effective charge on the surface (after making allowance for the diminution caused by firmly held counter ions) the values of the activity coefficient becomes approximately 0.25 and if, in the same case, the size of the micelle be neglected, the activity coefficient equals about 0.07. He also points out that the effect of increasing concentration would be a further reduction in the value of the activity coefficient.

The low values of  $a_{\text{H}}/c_{\text{H}}$ , as observed here, find an explanation in the light of these discussions if the existence of aggregate formation be assumed in this case as well. The nature of the  $\Lambda - \sqrt{c}$  curve in a way lends support to this view and shows the concentration where the formation of aggregates assumes considerable proportion to be near about 0.4 g./litre.

The increase of cataphoretic velocity with concentration should indicate an increase in the equivalent conductance of the micelle. Hartley reports a rise of equivalent conductance of the micelle ion in the aqueous solution of cetyl pyridinium bromide and McBain (*vide* Pauli and Valko, "Electrochemie der Kolloide", 1929, p. 584) reports a rise of transport number of the anions of many Na-soaps to values above unity. According to these workers this phenomenon has to be attributed to the aggregation of paraffin chain ions to form micelles. In the present system, since an increase in c. v. is evident from low concentrations (even below 0.40g./litre, where the  $\Lambda - \sqrt{c}$  curve exhibits its first break), a progressive aggregate formation from very low concentrations appears to be likely.

In the case of nucleic acid solutions—therefore, the critical concentrations, as indicated by the kinks in the  $\Lambda - \sqrt{c}$  curve, lose much of their significance if aggregate formation be assumed to start below these concentrations. In this the first break in the  $\Lambda - \sqrt{c}$  curve agrees with the first break in the  $a_{\text{H}}/c_{\text{H}} - c$  curve and therefore, from this point upwards the amount of active hydrogen ions per g. of the acid begins to decrease with concentration. This may be due to the arrest of more and more hydrogen ions in the double layer surrounding each micelle. A persistent increase in c. v. at this region and much further beyond this point, may probably be due to a marked increase in the size and charge density of the anion at low concentrations than at higher ones where the micelles acquire higher charge and bigger size so that the common effect of the change of concentration becomes evident.

An increase of c. v. and hence the equivalent conductance of the anion will necessarily indicate a very low value for the ionic conductance of the oppositely charged ion (*cf.* Hartley, *loc. cit.*). So there is little justification for calculation of specific conductivity of the acid from H-ion activity alone, as given in Table V, on the basis of a constant value of the ionic conductance of hydrogen ion equal to that at infinite dilutions. The progress of aggregate formation will arrest more and more

hydrogen ions in the double layer and will reduce its mobility and the effect is expected to be more prominent with increase in concentration. A correction for decrease in mobility of hydrogen ions will decrease the calculated value of specific conductivity and will tend to further increase the discrepancy between the calculated and observed values. A discrepancy between the observed and calculated values of sp. conductivity is, however, not very clear up till now.

The nature of the  $\epsilon$ - $c$  curve and a comparison of this with that obtained by the addition of  $\text{Ba}(\text{OH})_2$  into the system also serves to indicate the occurrence of aggregate formation in this case with increase in concentration. That the addition of  $\text{Ba}(\text{OH})_2$  serves to increase the size of the particles has also been confirmed by turbidity measurements (data to be presented in a subsequent communication).

To sum up, the evidences obtained in course of these investigations go to indicate the existence of aggregate formation which probably proceeds from very low concentrations and appears to be progressive at higher concentration regions.

Out best thanks are due to Dr. J. N. Mukherjee, C. B. E., D. Sc., Director, Indian Agricultural Research Institute for his keen interest and valuable suggestions in connection with this work.

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FATTY OIL FROM THE SEEDS OF *ARGYRIA SPECIOSA*,  
SWEET (N.O. CONVULVULACEAE)

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The seeds of *Argyria speciosa*, Sweet (N. O. Convolvulaceae) give a fatty oil which has been found to contain the glycerides of palmitic acid (6.78%), stearic acid (29.12%), behenic acid (6.64%), linolenic acid (6.09%), linolic acid (18.17%) and oleic acid, (88.23%).

*Argyria speciosa*, Sweet (N.O. Convolvulaceae), commonly known as elephant creeper, is abundant throughout India and is often cultivated in Java. It is known by the following names in different Indian languages : Samudra Patra (Sanskrit), Samudraka Pat (Hindi), Samudra Shosh (Gujarathi), Gaguili (Bengalee) and Samudra Shoka (Marathi). It is a large climber, having stout stems and broad round leaves and violet flowers like bells. The seeds have three sides of which one is convex and the other two plane. They are produced four together in a single capsular fruit. They are black when mature.

The roots of this creeper are bitter and are used as an alternative tonic. They are also useful in rheumatic affections and diseases of the nervous systems. In some parts of southern India, the tuber is used in the form of a paste for external application in abscess. The seeds along with the seeds of *Hygrophila spinosa*, T. Anders (N.O. Acanthaceae) are used as a tonic (*cf.* Kirtikar and Basu, "Indian Medicinal Plants", Vol. III, p.1707).

The seeds are extracted with different solvents. The petroleum ether extract gives a fatty oil, while all other extracts are yellowish gums.

The seeds contain 10.68% of a fatty oil of a pale yellow colour which does not contain nitrogen and sulphur. The oil on being hydrolysed the free fatty acids are separated into solid and liquid acids by Twitchell's lead salt-alcohol method. The liquid acids have been examined and found to contain linolenic acid (10.7%), linolic acid (31.6%) and oleic acid (57.7%).

The liquid acids have a mean molecular weight of 290.8 which suggests that they may contain a high molecular weight acid. The methyl esters of liquid acids have been prepared and fractionally distilled in order to isolate the high molecular weight acid, if present. The different fractions give high molecular weights and varying iodine values which indicate the absence of any high molecular weight acid. The high molecular weight of the mixed liquid acids may be due to the polymerisation of linolenic acid and linolic acid present (*cf.* Govindranjan, *Proc. Indian Acad. Sci.*, 1941, 14A, 616).

The solid acids have been converted into methyl esters, fractionally distilled, and different fractions hydrolysed and the mixtures of acids obtained are separated

into individual acids by fractional precipitation of their magnesium salts. Individual acids, thus separated, have been identified by their equivalent weights, melting points and mixed melting points with authentic specimens.

The free fatty acids of the oil have the following composition : palmitic acid, 6.73% ; stearic acid, 29.12% ; behenic acid, 6.64% ; linolenic acid, 6.09% ; linolic acid, 18.17% and oleic acid, 33.23%.

The unsaponifiable matter from alcohol is obtained in a crystalline condition (m.p. 129-30°) and gave all the colour reactions of phytosterols.

## EXPERIMENTAL

*Physical and Chemical Constants of the Oil*—The oil obtained by ether extraction from the seeds had the following constants.

TABLE I

1. Density at 30° ...	0.9251	2. Refractive index at 30° ...	1.4554
3. Iodine value (Hanus) ...	76.0	4. Saponification value (S.V.)...	197.45
5. Reichert Meissel value...	0.53	6. Acid value ...	1.815
7. Acetyl value ...	6.0	8. Unsaponifiable matter ...	0.3%

*Mixed Fatty Acids*.—The oil (100 g.) was saponified with alcoholic potash. The soap was dried and extracted with ether to remove the unsaponifiable matter. The soap was then dissolved in water and acidified with dilute sulphuric acid. The acids liberated were extracted with ether and worked up as usual. The mixed fatty acids, thus obtained, had the following constants : titre test, 39.0 ; equiv., 286.7 ; iodine value, 84.3 ; refractive index at 45°, 1.45648.

*Separation of Solid and Liquid Acids*.—The mixed fatty acids were separated into solid and liquid acids by Twitchell's lead salt-alcohol method and the acids were worked up as usual. The solid acids (43.5%) and liquid acids (56.5%) had the following constants.

TABLE II

	I.V.	Equiv. wt.	M.p.
Solid acid	66	287.0	51-52°
Liquid acid	145.0	290.8	—

*Identification of Solid Acids*.—The solid acids were converted into methyl esters by Fischer Speier method. The methyl esters (35.5 g.) were fractionally distilled at 53 mm. pressure. The results are given in Table III.



TABLE III

Fraction No.	B.p.	Wt.	Mean M.W.
I	Up to 210°	3.26 g.	—
II	210°-230°	10.0	275.3
III	230°-235°	8.8	285.0
IV	235°-240°	7.9	291.6
V	240°-250°	4.39	308.3
Residue	—	1.65	—

*Fraction I* was hydrolysed with alcoholic potash and the resulting acids (m.p. 57-58°, equiv. wt 257.5) on crystallisation from alcohol had m.p. 60-61° and equiv. wt., 256.4. The mixed melting point with an authentic specimen of palmitic acid was unchanged. Hence this fraction consists of methyl palmitate only.

*Fraction II* on hydrolysis gave a mixture of acids (m.p. 60-61° and equiv. wt. 275.5). The acids were then separated by fractional precipitation with magnesium acetate when palmitic acid (m.p. 61°; equiv. wt. 256.0) and stearic acid (m.p. 68-69°; equiv. wt. 282.8) were obtained. Hence this fraction is a mixture of methyl palmitate and methyl stearate.

*Fraction III* was entirely methyl stearate as on hydrolysis it gave an acid (m.p. 60°; equiv. wt. 285.9). On crystallisation it had m.p. 69° and equiv. wt. 285. Mixed melting point with an authentic specimen of stearic acid was unchanged.

*Fraction IV and Fraction V* consisted mainly of methyl stearate and methyl behenate as on hydrolysis and fractional precipitation by magnesium acetate (5 or 6 times) it gave pure stearic acid (m.p. 69° and equiv. wt 284) and behenic acid (m.p. 77-79°; equiv. wt. 339.6). Some of the intermediate fractions had m.p. 72-75° corresponding to that of arachidic acid but their equiv. wts. were always nearing that of behenic acid. This shows that these fractions consist mainly of methyl stearate and methyl behenate. If arachidic acid were present at all, it must be in a very small quantity.

*The residue* on hydrolysis and crystallisation gave an acid of m.p. 79° and equiv. wt. 339.6. Hence it must be entirely methyl behenate.

The composition of the solid acid therefore is palmitic acid, 15.85%; stearic acid, 68.53% and behenic acid, 15.63%

*Identification of Liquid Acids.*—The liquid acids were examined by the bromine addition method (Jamieson and Baughman, *J. Amer. Chem. Soc.*, 1920, 42, 2398). The liquid acids (5 g.) were dissolved in about 50 c.c. of dry ether and bromine was added to it drop by drop till a permanent yellow colour persisted, the temperature being kept at 0-5°. Hexabromostearic acid was obtained melting at 177-78° in 0.7242 g. yield. The filtrate was washed to remove the excess of

bromine and on drying and removing the ether, the residue was dissolved in petroleum ether and kept at 0° for 2 hours. The precipitate of tetrabromostearic acid, m.p. 112-13° was obtained in a yield of 1.6866 g. The residue (6.8864 g.) was worked up as usual and its bromine content was found to be 42.97%.

The percentage of bromine in the residue is higher than that corresponding to oleic acid dibromide (36.36%). Hence it is assumed that the same weights of tetra- and hexabromostearic acids have been retained in the residue. The composition of the liquid acids therefore becomes : linolenic, 10.7% ; linolic acid, 31.6% ; oleic acid, 57.7%.

Assuming the weights of tetra- and hexabromostearic acids retained in the residue (6.8864) as 1.6866 g. and 0.7242 g. respectively and calculating the bromine percentage in the residue, it is found that it comes very close to that actually estimated. (Found : Br<sub>2</sub>, 42.97. Calc., 43.5%). Hence the above assumption seems correct.

When the linolenic acid is brominated, mainly two hexabromostearic acids are formed, one being liquid and the other solid (*cf.* Hilditch, "The Chemical Constitution of Natural Fats", Chapman and Hall, 1940, p 337). The solid hexabromostearic acid being insoluble in ether crystallises out, while the liquid isomer remains in solution. In the calculation of the composition of liquid acids, the liquid hexabromostearic acid is not generally taken into consideration. In the present work it has, however, allowed for as indicated above.

The equiv. wt. of the liquid acids (290.8) indicates that some unsaturated acid of high molecular weight may be present. Hence methyl esters of liquid acids were prepared and fractionally distilled and the high boiling fractions were analysed but they showed high equiv. wt. and varying iodine values. Hence a high molecular weight acid cannot be present. High equiv. wt. of the acid is undoubtedly due to the polymerised products of linolic and linolenic acids. (*cf.* Govindranjan, *loc. cit.*).

The composition of the mixed fatty acids is therefore palmitic acid (6.73%), stearic acid (29.12%), behenic acid (6.64%), linolenic acid (6.09%), linolic acid (18.17%) and oleic acid (33.23%).

*Unsaponifiable matter.*—This was obtained by the extraction of the dry soap of the oil with ether. On three crystallisations from alcohol (charcoal) it was obtained in a crystalline form, m.p. 129-30°. It gave all the colour reactions of phytosterols. The quantity of the unsaponifiable matter being very small (0.3%), its further investigation could not be carried out.

FATTY OIL OF THE SEEDS OF *IPOMOEA MURICATA*  
JACQ. ( N.O. CONVULVULACEAE )

BY G. M. KELKAR, N. L. PHALNIKAR AND B. V. BHIDE

The seeds of *Ipomoea muricata*, Jacq. on extraction with ether gave a fatty oil (8.7%). The component acids of the fatty oil have been shown to be palmitic (18.61%), stearic acid (22.55%), behenic acid (3.78%), linolenic acid (3.92%), linolic acid (15.15%) and oleic acid (40.97%).

Our recent observation regarding the occurrence of behenic acid to the extent of 6.64% in the fatty oil from the seeds of *Argyria speciosa*, Sweet, (N. O. Convolvulaceae) has led us to the study of other fatty oils from the seeds of plants belonging to the same natural order. The present paper deals with the chemical examination of the fatty oil from the seeds of *Ipomoea muricata* Jacq. (N. O. Convolvulaceae).

*Ipomoea muricata*, Jacq. is a climber, commonly known as *Bhonvari*. It is known by the following names in different Indian languages: Small *Bhonvari* (Marathi), *Mirchi* (Hindi and Bengalee) and *Garayo* (Gujarathi.) It is an annual creeper growing in the rainy season. It has blue bell-shaped flowers. The seeds have three sides, two of which are plane and one convex. The seeds are black in colour when mature. The fruits and the seeds of this creeper are just similar to those of *Argyria speciosa*, Sweet.

The juice of the green leaves is used against bed bugs as it is believed to have insect-repellent properties. The seeds are said to be used as a purgative (*cf.* Desai, "Materia Medica and Therapeutics of Indian Medicinal Plants").

The seeds yield an oil (8.74%) when extracted with petroleum ether or sulphuric ether. The fatty acids of the oil have been separated into solid and liquid acids according to the usual procedure. The mixed fatty acids are found to have palmitic (13.6%), stearic (22.5%), behenic (3.78%), linolenic (3.91%), linolic (15.2%) and oleic acid (40.97%).

Hilditch ("The Chemical Constitution of Natural Fats", Chapman and Hall, 1940, p. 311) has remarked "Behenic acid is the chief constituent of behen oil. It is possibly present in very small proportions in a number of seed fats for example in groundnut oil, rapeseed oil and perhaps in other cruciferous seed oils. In none of these instances does it form more than 1% of the mixed fatty acids of the seed fat". The only other seed fat in which behenic acid occurs to a greater extent is *Parkia* seed fat investigated by Paranjape (*J. Indian Chem. Soc.*, 1931, 8, 767). In the light of these observations the presence of behenic acid to the extent of 3.784% in the fatty oil from the seeds of *Ipomoea muricata*, Jacq and to the extent of 6.64% in the fatty oil from *Argyria speciosa*, Sweet (*vide this issue*, p. 83) is worth recording. But it may be noted that these two plants belong to Convolvulaceae, while *Parkia* seeds belong to N O. Leguminosae.

Very few seeds from plants belonging to the N. O. Convolvulaceae have been studied. Some species of *Ipomoea* including *muricata* have been examined by Kassner (*Pharm. J.*, 1924, 112, 328). Kassner states that oils from these species have similar physical and chemical properties and are very similar to one another. Detailed examination of the oils, however, has not been carried out. Beside the seed oils of *Argyria speciosa*, Sweet and *Ipomoea muricata*, Jacq, the only other seed oil from plants belonging to this natural order which has been analysed is the seed oil from *Cuscuta reflexa*, Roxb (*Agarwall and Dutt, J. Indian Chem. Soc.*, 1936, 13, 264) but according to these authors it does not contain behenic acid. It is necessary therefore to study a number of seed oils of plants belonging to the N. O. Convolvulaceae before making a generalisation that the seed oils of plants belonging to Convolvulaceae contain behenic acid as one of the component acids.

Unsaponifiable matter from the seed oil of *Ipomoea muricata*, Jacq. is obtained in a crystalline form after several crystallisations from alcohol and melts at 131–32° (acetyl derivative, m. p. 119°). It gives all the colour reactions characteristics of phytosterols. Further work is in progress.

## EXPERIMENTAL

*Physical and Chemical Properties of the Oil.*—The finely powdered seeds (500 g.) were extracted with ether (sulphuric). The oil obtained had the following constants.

TABLE I

Density at 30°	...	...	0.9164	Saponifica-		
Refractive index at 30°	...	...	1.45288.	tion value	...	200.0.
Iodine value (Hanus)	...	...	68.57.	Acid value	...	1 606

*Mixed Fatty Acids*—The oil (40 g.) was saponified with sodium hydroxide. The soap after removing the alcohol was dried and extracted with ether to remove the unsaponifiable matter. The soap free from the unsaponifiable was dissolved in water and acidified with sulphuric acid. The liberated fatty acids were separated from water and dried. The mixed fatty acids are semi solid and have iodine value (Hanus). 76.0 ; equiv. wt., 286.0 ; titre test, 40.5.

*Separation of the Mixed Acids.*—The solid and liquid acids were separated by Twitchell's lead salt-alcohol method. The following table gives the percentage, equivalent weight and iodine value of the saturated and unsaturated acids.

TABLE II

	M.p.	Percentage,	Equiv. wt.	I. V.
Solid acids (saturated)	55–56°	40	285.6	0.1
Liquid acids (unsaturated)		60	280.0	127.1

*Identification of Solid Acids.*—Methyl esters of the solid acids were prepared by Fischer Speier method and the esters (8.7 g.) were fractionally distilled at 15mm. pressure.

The results of fractionation of the methyl esters of the solid acids are given in the following table.

TABLE III

Fraction No.	B p.	Wt.	Sapon. value.	Mean M. W.
I	Up to 200°	2.84 g.	207	257.1
II	200°-205°	1.6	189.42	283.6
III	205°-210°	2.84	183.2	290.6
IV	210°-225°	1.0	176.0	308.3
Residue	—	0.26	—	—

*Fraction I.*—This fraction on hydrolysis in the usual manner gave an acid having equivalent weight 257 and m. p. 60°. On crystallisation from alcohol it had m. p. 61-61.5° and equivalent weight 256. The mixed melting point with an authentic specimen of palmitic acid was unchanged. Hence this fraction contains methyl palmitate only.

*Fraction II.*—Hydrolysis of this fraction gave an acid, m. p. 65° and equivalent weight 283.4. On crystallisation it had m.p. 68-69° and equivalent weight 284, showing that this fraction consists of methyl stearate only.

*Fractions III and IV.*—These fractions were hydrolysed and the liberated acids had m.p. and equivalent weight as shown below. The acids from each of these fractions were separated into different fractions by fractional precipitation of their magnesium salts. The acids were dissolved in just sufficient quantity of alcohol and neutralised with sodium hydroxide.

Then magnesium acetate solution was added to precipitate a fraction of the total acids. The precipitated magnesium salt was separated, decomposed with hydrochloric acid and free acids were obtained in the usual manner. The following table gives equivalent weights and melting points of the acids from the filtrates and precipitates.

TABLE IV

	Fraction III	Filtrate IIIa	Precipitate. IIIb	Fraction IV	Filtrate IV a	Precipitate. IV b
Equiv. wt	290.6	283	329	308.3	288.4	331.9
M.p.	59°	66°	70°	60°	65°	70-71°

Fractions III (a) and IV (a) were identified as stearic acids by their equivalent weight and mixed melting point with an authentic specimen.

Fractions III (b) and IV (b) were mixed together and further fractionally precipitated as magnesium salt. The filtrate from the precipitation had m.p. 66° which on crystallisation was raised to 67°. The acids from the precipitated magnesium salts on the other hand had m.p. 77.5° which on recrystallisation was raised to 79-80°. The acid from the precipitated magnesium salts was further crystallised from alcohol when it melted at 80-81°, thus proving the presence of behenic acid. The fractions III and IV therefore contain methyl stearate and methyl behenate.

*Residue.*—As the quantity of the residue was very small (0.26 g.), the acid could not be identified and it was neglected in calculating the composition of the mixed fatty acids. The following table gives the composition of various fractions of methyl esters.

TABLE V

Fraction No.	Palmitic,	Stearic.	Behenic.	Total.
I	2.693 g.	—	—	2.693 g.
II	—	1.524 g.	—	1.524
III	—	2.834	0.375 g.	2.709
IV	—	0.588	0.367	0.955
Total	2.693	4.446	0.742	7.88

Hence the composition of the solid acids is : palmitic acid, 34.15% ; stearic acid, 56.39% ; behenic acid, 9.46%.

*Identification of the Liquid Acids.*—Liquid acids were examined by the bromine addition method (Jameison and Baughman, *J. Amer. Chem. Soc.*, 1920, 42, 2398). From 5g. of the liquid acids 0.439 g. of hexabromostearic acid was obtained, m. p. 179-80°. The filtrate was washed to remove the excess of bromine and on drying and removing ether, was dissolved in petroleum ether and kept at 0° for 2-hours. The precipitate of tetrabromostearic acid obtained was 1.330 g. and melted at 112-13°. The residue (7.06 g.) was worked out as usual and its bromine content was 41.16%.

The percentage of bromine in the residue is higher than that corresponding to the dibromostearic acid (36.36 %). Hence it is assumed that the same weight as solid tetrabromo and hexabromostearic acids is retained in the residue and then the percentage of different acids calculated.

The composition of liquid acids therefore comes out to be linolenic acid, 6.53% ; linolic acid, 25.15% and oleic acid, 68.28%.

Hence the composition of the mixed acids is : palmitic acid, 13.66% ; stearic acid, 22.55% ; behenic acid, 3.784% ; linolenic acid, 3.918% ; linolic acid, 15.15% ; oleic acid, 40.97%.

*Unsaponifiable matter.*—This was obtained by extracting the dry soap with ether after treatment with charcoal and crystallisation from alcohol ; it had m.p. 131-32°. When boiled with acetic anhydride and sodium acetate it gave an acetyl derivative, m.p. 118°. It gave all the characteristic colour reactions of phytosterol.

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## STEROID COMPOUNDS. PART I. A SYNTHESIS OF DESOXY-TESTOSTERONE\*

BY PRATUL CHANDRA MUKHARJI

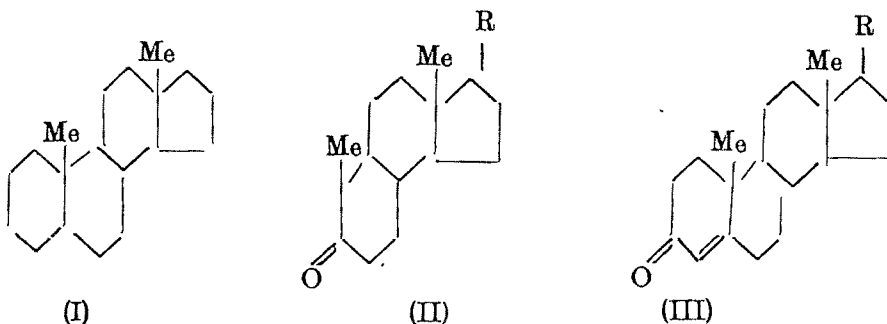
A synthesis of desoxy-testosterone is described.

The synthesis of alicyclic rings related to sex-hormones, sterols and bile acids has engaged the attention of chemists ever since the structures of the natural products were established. Besides the synthesis of equilenin and an isomer of oestrone (Bachmann *et al.*, *J. Amer. Chem. Soc.*, 1940, **62**, 824; 1942, **64**, 974) the synthesis of products belonging to this class, which are derived from *cyclopentano-perhydrophenanthrene* (I) ring system, remained a serious problem for synthetic organic chemists. One of the features of these compounds, which has been a formidable obstacle in the synthetic path, is the presence of angular methyl groups between the rings A-B and C-D of the steroid skeleton. Quite recently, Martin and Robinson (*J. Chem. Soc.*, 1943, 491) have synthesised a stereoisomer or a mixture of stereoisomers of androstendione, which is the first successful synthesis of a *cyclopentano-perhydrophenanthrene* derivative.†

The ingenious method developed by Mcquillin and Robinson (*J. Chem. Soc.*, 1937, 53) for the synthesis of  $\alpha\beta$ -unsaturated cyclic ketones containing an angular methyl group by condensing the methiodides of "Mannich" bases with cyclic ketones containing a keto-methin ( $-\text{CO}-\text{CHCH}_3-$ ) group, offers best promise of success for the synthesis of non-benzenoid steroids of testosterone type. An application of this method to tricyclic ketones of the type (II), permits the synthesis of testosterone (III, R=OH) and cholestenone (III, R=*sec-isooctyl*), provided the corresponding tricyclic ketones (II, R=OH; *sec-isooctyl*) are available (Robinson *et al.*, *loc. cit.* Robinson and Weygand, *J. Chem. Soc.*, 1941, 386). An attempt to build up the steroid skeleton by the above method therefore requires a convenient route to the tricyclic ketones of the type (II). Synthetic methods towards this end are, however, very limited and the methods so far successfully developed involve hydrogenation of suitable hydroaromatic derivatives.

\* A preliminary note was published in *Science & Culture*, 1945-46, **11**, 574.

† In a very recent publication (Cornforth and Robinson, *J. Chem. Soc.*, 1946, 676) it has been pointed out that "the attempt of Martin and Robinson (*loc. cit.*) to synthesise a stereoisomeride of androstendione broke down at the last stage, because the addition of a ring to BCD intermediate did not proceed so as to give ABCD which should have been structurally identical with androstendione, but afforded BCDE."

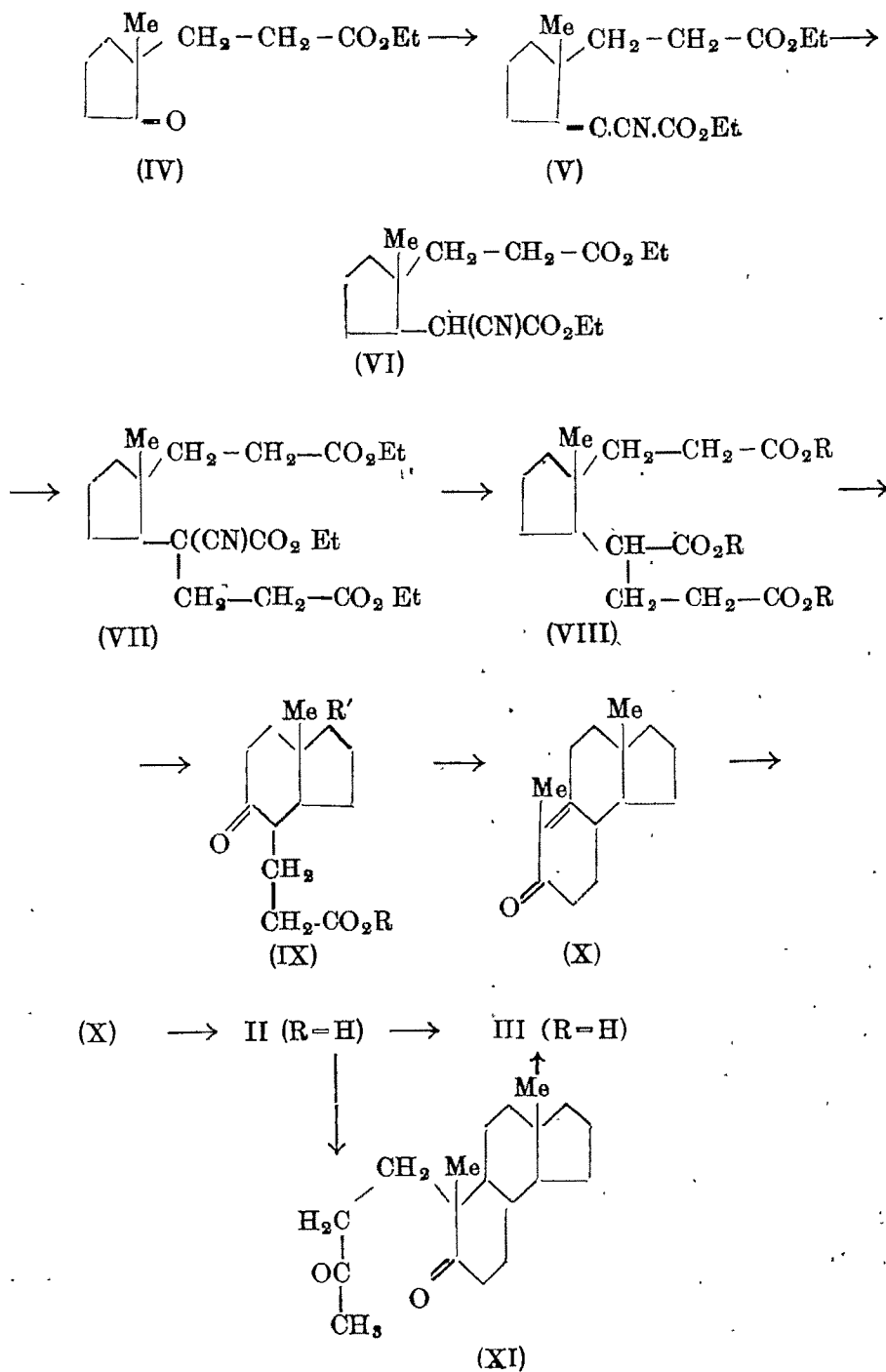


In the present communication is described a method that has been developed for the synthesis of tricyclic ketones of the type (II), which offers the possibility of application in the synthesis of *cyclopentano-perhydrophenanthrene* with the angular methyl groups and the side-chain characteristic of natural sterols. As a preliminary, the synthesis of 2:5-dimethyl-1:2-*cyclopentano-perhydronaphthalene-6-one* (II, R=H) has been successfully carried out and from this the tetracyclic ketone, desoxy-testosterone (III, R=H) has been obtained by an application of Robinson's "Mannich" base method.

The starting point of the present investigation is ethyl 2-methyl*cyclopentanone-2-β*-propionate (IV), which has been prepared from methyl *cyclopentanone* and ethyl *β*-bromopropionate. The above keto-ester (IV) has been condensed with ethyl cyanoacetate according to the method of Cope (*J. Amer. Chem. Soc.*, 1941, 63, 3452) to yield the unsaturated cyano-ester (V). Reduction of the above unsaturated ester with aluminium amalgam affords the saturated cyano-ester (VI) in an excellent yield, the potassium salt of which condenses smoothly with ethyl *β*-bromopropionate to yield the glutarate (VII). This has been hydrolysed by prolonged boiling with concentrated hydrochloric acid to the tricarboxylic acid (VIII, R=H); the triethyl ester (VIII, R=Et) of this acid smoothly undergoes Dieckmann's condensation in presence of sodium dust. The resulting *β*-keto ester has been hydrolysed with 20% H<sub>2</sub>SO<sub>4</sub> to the keto-acid (IX, R=R'=H) which affords the keto-ester (IX, R=Et; R'=H). This keto-ester is then reacted with activated zinc and ethyl-*α*-bromopropionate and the crude condensation product is hydrolysed with alcoholic caustic potash, when the unsaturated tricyclic ketone (X) is obtained on diluting the alkaline solution with water. The cyclisation during Reformatsky's reaction, observed here, is in harmony with the similar results recorded by Adamson, Mcquillin, Robinson and Simonsen (*J. Chem. Soc.*, 1937, 1576). The unsaturated ketone on hydrogenation in presence of Adam's catalyst in alcohol furnishes the saturated ketone (II, R=H). This tricyclic ketone is next condensed with the methiodide of 4-diethylaminobutan-2-one under usual conditions (Martin and Robinson, *loc. cit.* Ghosh and Robinson, *J. Chem. Soc.* 1944, 506) and the higher boiling product obtained has been found from the analytical data to be a mixture of the desired tetracyclic ketone (III, R=H) and the intermediate diketone (XI). It is treated with dry sodium methoxide in benzene solution and the neutral product on



sublimation in *vacuo* affords the tetracyclic ketone (III, R=H) as a pale yellow highly viscous oil.



An extension of the above reactions to 2-methyl-3-*isooctylcyclopentanone* (Mukherjee, *Science & Culture*, 1941-42, 7, 58) will eventually lead to the formation of a compound possessing cholestenone structure and this work is in progress.

It may be of interest to point out here that the problem of the construction of natural steroid skeletons becomes much simplified if a convenient simpler route to 0 : 3 : 4-bicyclononane derivatives of the type IX ( $R = Et$ ;  $R' = \text{substituent}$ ) is worked out. The condensation of substituted 2-methylcyclopentanones e.g., 2-methyl-3-*isooctylcyclopentanone* and related compounds, with the methiodide of  $(Et)_2N \cdot CH_2CH_2COCH_2CH_2CH_2CO_2Et$  in presence of sodamide appears to be a very attractive route to bicyclic systems of the type (IX). Work along this line is well under way and the results will be the subject matter of a future communication. Other routes to the derivatives of this important intermediate (IX) are also being investigated.

#### EXPERIMENTAL

*Ethyl 2-Methylcyclopentanone-2 $\beta$ -propionate* (IV).—A mixture of *ortho*-methylcyclopentanone (49 g.), powdered sodamide (21 g.) in dry ether (800 c. c.) was stirred under reflux for 5 hours. The volume of ether was then reduced to 300 c. c. (Dutta, *J. Indian Chem. Soc.*, 1940, 17, 649) and ethyl  $\beta$ -bromopropionate (93 g.) was added to the above sodio salt cooled in ice in course of 20 minutes with constant stirring. After addition was complete the temperature was gradually raised and the ethereal solution refluxed for 3 hours. It was then decomposed with ice and ethereal layer separated, washed with water and dried. After removal of the solvent the residue was distilled and the fraction boiling at 125-145°/10 mm. as a colourless mobile liquid (40 g.) was collected. A higher boiling residue was left in the flask which was not investigated.

A mixture of the above condensation product (40 g.) and ethyl oxalate (29.5 g.) cooled in a freezing mixture was gradually added to a solution of sodium ethoxide, prepared from sodium (4.6 g.) in alcohol (60 c. c.), similarly cooled in a freezing mixture (-20°) with constant shaking and the mixture left overnight in the freezing bath, tightly corked. The red solution was next poured into cold water and extracted with ether and the ethereal layer separated. The alkaline solution was next acidified and the precipitated oil extracted with ether.

The crude oxalyl derivative, obtained on removal of ether, was then hydrolysed with baryta (134 g.) and water (670 c. c.) for 3 hours when the oil completely passed into solution. It was extracted with ether to remove any neutral matter that might be present and the alkaline solution then acidified and repeatedly extracted with ether and the crude acid, obtained on the removal of solvent, was esterified with alcohol (100 c.c.) and concentrated  $H_2SO_4$  (6 c. c.) for 15 hours. The ester was worked up in the usual way and distilled at 130°/9 mm. as a colourless mobile liquid, yield 30 g. (Found; C, 66.31; H, 8.96.  $C_{11}H_{18}O_3$  requires C, 66.67; H, 9.1 per cent). The

*semicarbazone* crystallised from dilute methanol as small needles, m. p. 80-81°. (Found : C, 55.9 ; H, 8.08.  $C_{12}H_{21}O_3N_3$  requires C, 56.47 ; H, 8.23 per cent).

*Ethyl 2-Methyl-2-β-carbethoxyethylcyclopentylidenecyanoacetate* (V).—The above keto-ester (50 g.), ethyl cyanoacetate (30 g.), ammonium acetate (5 g.), glacial acetic acid (15 c.c.) in benzene (100 c.c.) were refluxed for 10 hours in a flask fitted with a water separator (*cf. Cope et al., loc. cit.*). The benzene solution was then repeatedly washed with water and the benzene removed under reduced pressure. The residue was fractionated and the unsaturated cyano-ester (25 g.) collected at 174°/2.5 mm. as a pale yellow viscous liquid. (Found : C 65.8 ; H, 8.0.  $C_{16}H_{23}O_4N$  requires C, 65.5 ; H, 7.85 per cent).

The low boiling fractions containing the unchanged keto-ester and cyanoacetic ester were again treated as before when a further quantity (13 g.) of the unsaturated cyano-ester was obtained. During this condensation with recovered materials a crystalline solid distilling between 150° and 160°/2.5 mm. was obtained as a byproduct, the amount of which increased considerably when a third condensation with recovered materials was attempted. The character of this abnormal product is under investigation.

*Ethyl 2-Methyl-2-β-carbethoxyethylcyclopentylcyanoacetate* (VI).—The above unsaturated cyano-ester (35 g.), aluminium amalgam (prepared from 30 g. of aluminium foil), rectified spirit (2 c.c.) in moist ether (500 c.c.) were left at the ordinary temperature for 7 days. The ethereal solution together with the aluminium sludge was cooled in a freezing mixture and then poured into ice-hydrochloric acid mixture (Bagchi and Banerjee, *J. Indian Chem. Soc.*, 1946, 23, 377). The ethereal layer separated and the aqueous solution extracted with ether. The combined ethereal extracts were washed with water, dilute bicarbonate solution and dried. The residue left on removal of the ether was distilled and the saturated cyano-ester (30g.) collected at 157-59°/2 mm. as a colourless mobile liquid. (Found : C, 65.8 ; H, 8.5.  $C_{16}H_{25}O_4N$  requires C, 65.1 ; H, 8.5 per cent).

*Ethyl α-Cyano-α-(2-methyl-2-β-carbethoxyethylcyclopentyl) glutarate* (VII).—Ethyl β-bromopropionate (18 g.) was added to the potassio derivative of the above cyanoacetic ester (VI), prepared from potassium (3.7 g.), cyano-ester (28 g.) and xylene (100 c.c.). The reaction mixture was left overnight, then heated on the water-bath for 4 hours and finally refluxed in an oil-bath for 6 hours. The reaction product was worked up in the usual way and distilled, b.p. 195-97°/3 mm., yield 24 g. (Found : C, 64.2 ; H, 8.32.  $C_{21}H_{32}O_6N$  requires C, 63.8 ; H, 8.35 per cent).

*Ethyl α-(2-Methyl-2-β-carbethoxyethylcyclopentyl) glutarate* (VIII, R = Et).—The above substituted cyano-ester (23 g.) was hydrolysed by refluxing with concentrated hydrochloric acid (200 c.c.) for 70 hours, when the tribasic acid (VIII, R = H) was obtained as white shining crystals together with an adhering gum. It was crystallised from concentrated hydrochloric acid, m.p. 170-72°. (Found : C, 58.2 ; H, 8.0.  $C_{14}H_{22}O_6$  requires C, 58.74 ; H, 7.7 per cent).

The tricarboxylic acid was then esterified with alcohol (60. c.c.) and concentrated  $\text{H}_2\text{SO}_4$  (8 c.c.) for 30 hours and the ester worked up in the usual way and distilled, b.p.  $166-68^\circ/2.5$  mm., yield 17g. (Found : C, 64.36 ; H, 8.98.  $\text{C}_{20}\text{H}_{34}\text{O}_6$  requires C, 64.86 ; H, 9.19 per cent).

*Ethyl 8-Methyl-0 : 3 : 4-bicyclononane-5-one-4- $\beta$ -propionate* (IX, R = Et ; R' = H) —The above pimelate (16 g) was refluxed with sodium dust (2 g.) in benzene (80 c.c.) until the whole of the sodium had reacted. The reaction mixture was decomposed with ice and dilute sulphuric acid and the benzene layer separated. The benzene solution was washed with dilute bicarbonate solution, then with water and dried. Benzene was removed under diminished pressure and the  $\beta$ -keto ester distilled, b.p.  $157-59^\circ/3$  mm. (Found : C, 66.3 ; H, 8.56  $\text{C}_{18}\text{H}_{28}\text{O}_5$  requires C, 66.66 ; H, 8.64 per cent) The  $\beta$ -keto ester gave an intense violet coloration with alcoholic ferric chloride.

The  $\beta$ -keto ester was hydrolysed by refluxing with 20% sulphuric acid (150 c.c.) for 30 hours in an oil-bath. The acid (IX, R = R' = H) was extracted with ether, washed with water and dried over anhydrous sodium sulphate. The residue left on removal of ether was thoroughly dried in vacuum and esterified with alcohol (75 c.c.) and concentrated sulphuric acid (4 c.c.) for 20 hours. The keto-ester was worked up in the usual way and distilled, b.p.  $144-46^\circ/3.5$  mm., yield 8 g. (Found : C, 70.6 ; H, 9.47.  $\text{C}_{15}\text{H}_{24}\text{O}_3$  requires C, 71.4 ; H, 9.5 per cent).

The semicarbazone, prepared in the usual way, was obtained in silky needles from dilute alcohol, m. p.  $158-60^\circ$ . (Found : C, 62.26 ; H, 9.1.  $\text{C}_{18}\text{H}_{27}\text{O}_3\text{N}_3$  requires C, 62.14 ; H, 8.73 per cent).

*2 : 5-Dimethyl-1 : 2-cyclopentano  $\Delta^{5:10}$ -octahydronaphthalene-6-one* (X).—The above keto-ester (7.5 g.) was refluxed with a mixture of thiophene-free benzene (16 c. c.), activated zinc (2 g.), ethyl  $\alpha$ -bromopropionate (5.5 g.) and a crystal of iodine. A vigorous reaction set in within 15 minutes and the whole of the zinc passed into solution within one hour. The heating was continued for 1 hour more and the product decomposed with iced dilute sulphuric acid, extracted with benzene, washed with dilute ammonia and water. The residue left on the removal of benzene was then hydrolysed with 10% alcoholic KOH (7.5 g.) solution for 2 hours and the alkaline solution poured into water when an oil separated which was repeatedly extracted with ether. The ethereal layer was washed with water and dried over anhydrous sodium sulphate. On removal of the ether, a brown oil with a very characteristic odour was obtained. It distilled at  $139-140^\circ/3$  mm. as a pale yellow oil, yield 2.5 g. (Found : C, 81.82, 82.34 ; H ; 10.10, 9.9.  $\text{C}_{15}\text{H}_{22}\text{O}$  requires C, 82.56 ; H, 10.1 per cent).

The unsaturated ketone furnished a semicarbazone instantaneously in the cold which crystallised from alcohol in minute shining crystals, m. p.  $207^\circ$ . (Found : C, 69.8 ; H, 9.2  $\text{C}_{16}\text{H}_{25}\text{ON}_3$  requires C, 69.8 ; H, 9.1 per cent).

The alkaline solution was acidified, extracted with ether and the acid esterified to yield the unreacted keto-ester (IX). This yielded a further quantity of

the unsaturated ketone (1.2 g.) on treatment with zinc and ethyl  $\alpha$ -bromopropionate.

2 : 5-Dimethyl-1 : 2-cyclopentanoperhydropentalene-6-one (II, R = H).—The unsaturated ketone (3.2 g.) was hydrogenated over Adam's catalyst (0.2 g.) until one mole of hydrogen had been absorbed (3 hours). The alcoholic solution was filtered off from the catalyst and the saturated ketone distilled, b. p. 132-33°/3 mm. A small quantity of a higher boiling product was left in the flask which was not investigated. The saturated ketone was obtained as a colourless viscous oil possessing a very sweet odour resembling "Khus". (Found : C, 81.3 ; H, 10.9.  $C_{15}H_{24}O$  requires C, 81.8 ; H, 10.9 per cent).

The ketone furnished a semicarbazone readily in the cold which after crystallisation from alcohol melted at 224°. (Found : C, 69.32 ; H, 9.3.  $C_{16}H_{27}ON_3$  requires C, 69.31 ; H, 9.7 per cent).

Desoxy-testosterone (III, R = H).—The above tricyclic ketone (2.2 g.), powdered sodamide (0.5 g.) and ether (40 c. c.) were stirred under nitrogen at room temperature for 5 hours, then cooled in ice while a solution of 4 diethylaminobutan-2-one (from 1.8 g. of base) in alcohol (12 c. c.) was added in the course of 10 minutes. Stirring continued in the cold for 3 hours, then at the ordinary temperature for another 2 hours and the mixture left overnight in an atmosphere of nitrogen. It was then refluxed for 1 hour, cooled and poured into ice-hydrochloric acid mixture and the product isolated with ether. The ethereal layer was washed with water, dilute NaOH solution and again with water. After drying over anhydrous sodium sulphate, the solvent was removed and the residue distilled. At first the unreacted ketone (1 g.) distilled at 110-140°/1 mm. (bath temp.) followed by a fraction which distilled at 160-170°/0.1 mm. (bath temp.) as a yellow glass. (Found : C, 79.9, 79.8 ; H, 9.9, 10.1.  $C_{19}H_{28}O$  requires C, 83.8 ; H, 10.29.  $C_{19}H_{30}O_2$  requires C, 78.6 ; H, 10.3 per cent).

The substance was obviously a mixture of the required tetracyclic compound and the intermediate diketone (XI). It was next treated with dry sodium methoxide (0.1 g.) in benzene (30 c. c.) and left overnight. Next day it was heated at 60° for 1 hour and poured into cold water. Benzene layer was separated, washed with water and the residue left on removal of benzene was sublimed and a fraction boiling at 150-155°/0.08 mm. (bath temp.) as a pale yellow highly viscous oil was collected. (Found : C, 83.14 ; H, 10.18.  $C_{19}H_{28}O$  requires C, 83.8 ; H, 10.29 per cent).

The author is grateful to Prof. P. C. Mitter for his valuable advice and encouragement during the course of this investigation and for the facilities provided ; to Prof. S. N. Bose for his keen interest and valuable criticism ; to Dr. D. K. Banerjee for his advice and generous help throughout the investigation ; to Dr. P. C. Dutta for a gift of the starting materials and to Mr. N. Ghosh, M. Sc. for the micro-analysis of most of the compounds.

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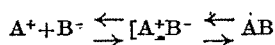
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# CONDUCTANCE OF SALTS IN NON-AQUEOUS SOLVENTS. PART II.

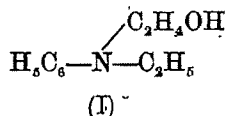
## CONDUCTANCE OF SALTS IN ETHYLPHENYLETHANOLAMINE

By S. K. BHATTACHARYYA AND S. N. NAKHATE

Conductivities of a number of electrolytes, e. g., tetraethylammonium chloride, tetramethylammonium picrate, ethylamine picrate, ethylamine hydrochloride, nitrophenol, sodium, benzamide and sodium picrate, were determined under different experimental conditions using ethylphenylethanolamine as a solvent. The results presented in this paper show a great contrast to those in triethanolamine as a solvent (Part I of this series). The  $\lambda_c - \sqrt{c}$  curves are much steeper and cannot be trusted to give even approximate values of  $\lambda_\infty$ . These curves show minima. After the minimum the conductivity rises sharply towards higher concentration. In the case of tetraethylammonium chloride, which was studied in a wide range of concentration, in addition to a minimum, a maximum occurs. It has been found in all cases that the portion of the curve beyond the minimum towards greater dilution has a slope of  $-\frac{1}{2}$ , which shows that the mass action law holds good between ions and ion-pairs, thus :



The object of the present investigation was to study the electrical conductance of solutions of uni-univalent electrolytes in ethylphenylethanolamine as a solvent. Ethylphenylethanolamine (I), should behave as an alcohol as well as a base. It has a fairly high viscosity but has a low dielectric constant.



The following electrolytes have been studied: (a) tetraethylammonium chloride, (b) tetramethylammonium picrate, (c) ethylamine picrate, (d) ethylamine hydrochloride, (e) *p*-nitrophenol, (f) sodium, (g) benzamide and (h) sodium picrate.

### EXPERIMENTAL

The experimental procedure was the same as in Part I of this series (*J. Indian Chem. Soc.*, 1947, 24, 1).

The dielectric constant of ethylphenylethanolamine was measured by using an apparatus used by Nagamani and Jatkar (*J. Ind. Inst. Sci.*, 1941, 24A, 81). The dielectric constant was found to be 8.55 at 25°.

The viscosity of ethylphenylethanolamine was measured by both Ostwald and Redwood methods and was found to be 0.526 poises.

*Preparation and Purification of materials.*—Ethylphenylethanolamine supplied by the Carbide and Carbon Chemical Corporation was distilled under reduced pressure. The middle fraction of the distillate was dried over fused potassium hydroxide and was redistilled twice. This gave a very faintly yellowish liquid of sp. gr. 1.04. As the specific conductivity was considerably lower than  $1 \times 10^{-8}$ , it could not be accurately measured in our apparatus. The specific conductivity being very low, the solvent correction was negligible and so it was not applied.

Tetraethylammonium chloride, ethylamine hydrochloride and sodium derivative were prepared as stated in Part I (*loc. cit.*). The picrates were prepared by adding a

hot solution of picric acid to the hot solution of tetramethylammonium chloride and ethylamine hydrochloride. The crystals, separated on cooling, were washed with 95% alcohol and recrystallised several times from water-alcohol mixtures.

Pure nitrophenol was recrystallised from xylene and dried at 120°. Sodium picrate was prepared from 'A. R.' sodium hydroxide and picric acid and was purified by repeated crystallisations. Benzamide was recrystallised three times from water-alcohol mixtures.

The solvent and all the electrolytes were perfectly dried and preserved in a vacuum desiccator.

The results are recorded in Tables I to V. In the following tables,  $c$  is the concentration in gram-equivalents per litre,  $\kappa$  is the specific conductivity and  $\lambda_c$ , the equivalent conductivity. In Table V are summarised the results for electrolytes which are extremely weak. Their conductivities at lower concentrations are too low to be measured with any degree of accuracy.

TABLE I

Electrolyte = Et<sub>4</sub>NClO<sub>4</sub>. Temp. = 25°.

Temp. = 25° C					
$c.10^3$	$\lambda_c.10^3$	$c.10^3$	$\lambda_c.10^3$	$c.10^3$	$\lambda_c.10^3$
1.424	48.51	65.88	33.44	478.37	52.11
5.431	27.99	127.7	44.49	602.7	52.16
18.42	19.51	309.1	50.89	823.7	49.76
37.99	25.34	326.0	52.72	1075.0	42.85

TABLE II

TABLE III

TABLE IV

Me <sub>4</sub> N-picrate. Temp. = 25°.		EtNH <sub>2</sub> -picrate. Temp. = 25°.		EtNH <sub>2</sub> .HCl. Temp. = 25°.	
$c.10^3$	$\lambda_c.10^3$	$c.10^3$	$\lambda_c.10^3$	$c.10^3$	$\lambda_c.10^3$
2.956	17.35	0.9294	25.93	26.98	2.159
10.35	12.77	2.905	15.08	97.86	1.980
22.25	11.48	7.435	9.705	291.0	3.115
31.46	10.92	15.48	10.43	616.0	4.584
41.30	10.71	28.60	6.133		
		44.32	9.998		

TABLE V

Temp. = 25°

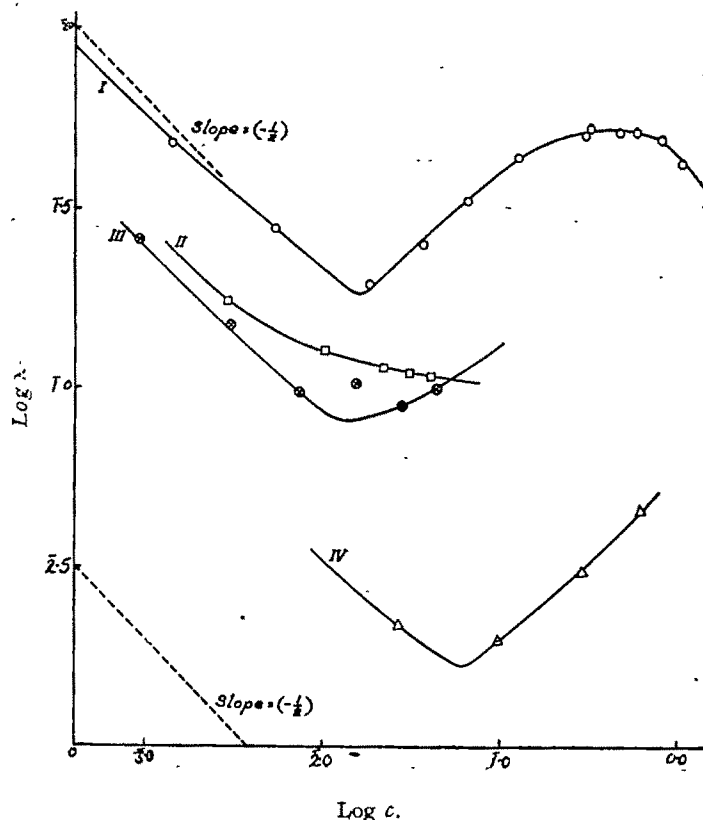
Electrolyte.	$c$ .	$\kappa$ .	$\lambda_c$ .	Electrolyte.	$c$ .	$\kappa$ .	$\lambda_c$ .
p-Nitrophenol	$5.0 \times 10^{-2}$	$1.335 \times 10^{-7}$	$2.67 \times 10^{-3}$	Benzamide	$1.46 \times 10^{-1}$	$1.569 \times 10^{-7}$	$1.07 \times 10^{-3}$
	$2.0 \times 10^{-1}$	$6.929 \times 10^{-7}$	$3.464 \times 10^{-3}$	Na picrate	$1.52 \times 10^{-3}$	$1.112 \times 10^{-7}$	$7.3 \times 10^{-2}$
Na derivative					$8.480 \times 10^{-3}$	$2.463 \times 10^{-7}$	$2.9 \times 10^{-2}$
EtN—Ph	$3.0 \times 10^{-2}$	$1.962 \times 10^{-7}$	$6.54 \times 10^{-3}$				
C <sub>2</sub> H <sub>5</sub> ONa							

## DISCUSSION

The results recorded above show a great contrast to those in triethanolamine as a solvent. The  $\lambda_c - \sqrt{c}$  curves are much steeper and cannot be trusted to

give even approximate values of  $\lambda_c$ . These curves show minima. All the electrolytes behave as weak electrolytes.

FIG. 1

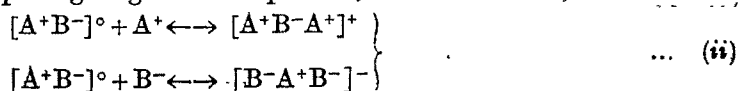


Curves I—IV refer respectively to  $\text{Et}_4\text{NClO}_4$ ,  $\text{Me}_4\text{N}$  picrate,  $\text{EtNH}_2$  picrate and  $\text{EtNH}_2\cdot\text{HCl}$ .

In the case of solvents of high dielectric constant, the departure from the simple Ostwald's dilution law can be satisfactorily explained by taking into consideration the effect of the ion-atmosphere. But when the dielectric constant is lowered, this ion-atmosphere effect becomes smaller and smaller, while the effect due to ion-association increases. Kraus and Fuoss (*J. Amer. Chem. Soc.*, 1933, 55, 21,) have pointed out that in the dielectric constant range between 10 and 20, it is necessary to take into account the equilibrium between free ions and ion-pairs.



This accounts for the rapid falling away of the equivalent conductance below values required by the Debye-Hückel-Onsager slope and for the linearity of the  $\log \lambda_c$  vs  $\log c$  plots. In solvents of still lower dielectric constant ( $D < 10$ ), an equilibrium between free ions and ion-pairs giving rise to triple ions, must be considered :





This equilibrium will have an increasing influence as the dielectric constant is lowered. This accounts for the deviation of the  $\log \lambda_c - \log c$  curves from linearity in the dilute solutions and for the occurrence of the conductance minimum at higher concentrations.

The application of the law of mass action to this equilibrium between ions and ion-pairs (†) above, when the degree of dissociation is small in comparison with unity, i.e. when it is represented fairly accurately by  $\lambda_c/\lambda_0$ , shows

$$\kappa = \frac{c\gamma^2}{1-\gamma} = \frac{c\gamma^2}{1} = c(\lambda_c/\lambda_0)^2.$$

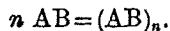
From this it is clear that  $\frac{d \log \lambda}{d \log c} = -\frac{1}{2}$ . Thus, if the mass action law holds good between ions and ion-pairs, a plot of  $\log \lambda$  against  $\log c$  should have a slope of  $-1/2$ . This has been observed by Fuoss *et al.* (*J. Amer. Chem. Soc.*, 1933, 55, 21, 476, 1019, 2387; 1935, 57, 2604; 1940, 62, 506, 2238; *Trans. Faraday Soc.*, 1934, 30, 67; *Chem. Rev.*, 1935, 17, 27) in a number of solvents. It can be seen from Fig. 1 that all the four electrolytes studied in ethylphenylethanolamine conform to this. The dotted lines which have the slope  $(-1/2)$  are almost parallel to the portion of the curve beyond the minimum towards greater dilution.

Minima are observed in all cases. After the minimum the conductivity rises sharply towards higher concentration.

In the case of tetraethylammonium chlorate, which was studied in a wide range of concentration, in addition to a minima, a maximum occurs. Walden has observed the same phenomenon in a number of solvents and states that a maximum generally occurs at approximately one normal. The maximum observed here is approximately at 0.6 *N*.

Kraus and Fuoss (*loc. cit.*) have derived equations from which the mass action constant can be theoretically calculated and a curve can be drawn theoretically to represent  $\lambda_c - \sqrt{c}$  relations. These equations have not been applied in this part as (a) extrapolated values of  $\lambda_0$  in this case are at best gross approximation, (b) the critical concentration,  $c_0$  for ethylphenylethanolamine is  $1.96 \times 10^{-4}$ , which means that even the lowest concentrations used in the investigation are more than a hundred times of  $c_0$ .

At these concentrations, the association effects may become more complex, aggregates of higher order than ion-pairs and triple ions must be considered:



These highly complicated association processes determine the course of nearly all the measurable properties of solutions in non-polar media.

The authors wish to express their thanks to Sir J. C. Ghosh for the interest he has taken throughout the investigation. Our thanks are due to Dr. S. K. K. Jatkar for his kind help in making the measurements of dielectric constants.

PHYSICO-CHEMICAL STUDIES OF COMPLEX FORMATION BETWEEN  
MOLYBDIC AND TARTARIC ACIDS. PART IV. PHOTOCHEMICAL  
REDUCTION OF MOLYBDIC ACID IN PRESENCE OF *d*-TAR-  
TARIC ACID AND THE INFLUENCE OF REDUCTION ON  
OPTICAL ROTATION

BY ANIL BHUSAN BISWAS

The kinetics of the photochemical reduction of molybdic acid in presence of *d*-tartaric acid have been studied and the quantum efficiency of the process has been measured. The dependence of the rate of reduction on the concentrations of both complex and uncombined molybdic acid, its variation with change of pH of the system and the appearance of different shades of the reduced solutions, have been explained. Evidence from rotation measurements of the reduced solutions indicates that the complex does not break into its components by reduction.

Benrath (*Z. wiss. Photochem.*, 1917, 16, 253) observed blue coloration after short exposure to sun light, in an aqueous solution of ammonium molybdate in presence of either ethyl or methyl alcohol and stated that the complex formed and not neutral molybdate, was reduced, the colour being due to the blue oxide  $\text{Mo}_3\text{O}_8$ . Courtius (*Bull. soc. chim.*, 1923, 33, 1773) observed that uranyl tartrate was stable in the dark but rapidly reduced in sunlight to a dull yellow compound in the absence of air. Dumanskii and Diatschkovsky (*J. Russ. Phys. Chem. Soc.*, 1928, 60, 1053) exposed to light a solution of sodium tungstate in tartaric acid and attributed the blue colour to the formation of a reduced colloidal complex. Bhattacharyya and co-workers (*J. Indian Chem. Soc.*, 1942, 19, 510) have studied the photo-reduction of ammonium molybdate by tartaric, mandelic and lactic acids in the ultraviolet ( $366\mu$ ) and found that the reduction velocity varied with the colour of the reduction product, the velocity being maximum when the end-product was pale yellow and diminishing when green products were formed.

Ghosh and collaborators (*J. Indian Chem. Soc.*, 1937, 14, 495 *et seq.*) have made extensive investigations on the photo-reduction of various photo-active sols by various reducing agents like alcohols and organic acids; the mechanism of those reactions have been explained on the assumption that active centres are created on the colloid surface by absorption of light which start the reactions. The object of the present investigation is to throw further light on the process.

EXPERIMENTAL

The reaction cell (4 cm.  $\times$  4 cm.  $\times$  1 cm.), made of plane glass fused into one another with a glass stopper at the top, was placed inside a double jacketted metal box and its temperature was kept constant by circulating water; the light coming from a quartz-mercury arc lamp was condensed with a suitable quartz lens and from the emergent rays the spectral region  $366\mu$  was isolated with the help of a "Schott and Gen ultra-violet filter No. 312". The arc lamp was supplied with a steady current at 220 volt and the distance of the reaction cell from the light source was kept constant.

*Reagents.*—B. D. H.'s pure *d*-tartaric acid was further purified by recrystallisation from redistilled water. Pure NaOH solution free from carbonate was used. The preparation of molybdic acid sol from ammonium molybdate and HCl was described in a previous communication. Redistilled water was always used for making solutions.

*Measurement of Reaction Velocity.*—This was determined by pipetting out 5 c. c. of the reaction mixture into a glass stoppered conical flask containing dilute  $H_2SO_4$  and titrated with  $0.6688 \times 10^{-2} N$ - $KMnO_4$  solution from a micro-burette. It is to be noted here that the end-point of this titration is very fugitive, although the  $KMnO_4$  solution cannot appreciably react with tartaric acid solution when present separately at the same concentration as present in its mixture. The titration was carried out as quickly as possible and the first appearance of the pink colour was taken as the end-point.

The reduction of molybdic acid ( $MoO_3$ ) in presence of tartaric acid ( $H_2T$ ) did not appear to take place in the dark within 6 hours, but on long standing (15 days) in the dark, indications of slight reduction were observed from the faint blue colour. The reduction rate in the dark was therefore extremely slow but on short exposure to ultra-violet light the reduction started immediately.

The rate of reductions by radiation of  $366\mu$  of mixtures at different concentrations of both molybdic and tartaric acids has been studied here and also of similar mixtures at different  $p_H$  brought about by the addition of a suitable quantity of NaOH solution. The  $p_H$  was measured with glass electrode as before. The velocity of reaction expressed as  $dx/dt$ =zero-molecular velocity constant=changes in concentration of 5 c.c. of the reaction mixture per minute in terms of volume of  $0.6688 \times 10^{-2} N$   $KMnO_4$  solution. Previous to exposure to light, the reaction mixture in the cell was freed from dissolved oxygen by bubbling pure nitrogen for sometime in the dark and then fixing and sealing the stopper with wax. The velocity of reduction of molybdic acid sol with varying concentration of tartaric acid at  $25^\circ$  is shown below.

TABLE IA

Reduction by full radiation from Hg-arc lamp, the cell being placed at a distance of 15 cm.

Conc. of $MoO_3$	Conc. of $H_2T$ .	$p_H$ .	$dx/dt$ .	Colour of the product.
$2.36 \times 10^{-2} M$	$0.57 \times 10^{-2} M$	2.32	$73.10 \times 10^{-4}$	Deep blue
"	1.14	2.12	130.0	"
"	2.36	2.06	150.0	Pale blue
"	4.68	1.90	133.0	Pale yellow with greenish tinge
"	9.37	1.87	73.0	Pale yellow

TABLE IB

Reduction by ultraviolet light— $366\mu$ .

Conc. of $MoO_3$ .	Conc. of $H_2T$ .	$p_H$ .	$dx/dt$ .	$k_0 \times 10^{11}$ .	$I_{abs.} \times 10^{11}$ .	$\nu$ .	Colour of the product.
$2.6 \times 10^{-2} M$	$0.65 \times 10^{-2} M$	2.29	$33.3 \times 10^{-4}$	7.42	35.95	0.20	Deep blue
"	1.30	2.09	46.6	10.39	34.40	0.30	"
"	2.60	1.99	50.0	11.15	28.06	0.39	Pale blue
"	5.21	1.82	33.3	7.42	19.24	0.38	Pale yellow with greenish tinge
"	10.43	1.75	26.6	5.93	13.80	0.43	Pale yellow

In the above table and also in the following, the quantum efficiency  $\nu \left( = \frac{k}{I_{\text{abs}}} \right)$  of the process of photo-reduction has been calculated thus: it has been assumed that one mole of  $\text{KMnO}_4$  reproduces 5 moles of reduced molybdic acid to the original oxidant stage according to the equation  $\text{Mn}_2\text{O}_3 + \text{O} \rightarrow 2\text{MoO}_3$ , and thus the zero molecular velocity constant is recalculated and given in the table as  $k_0$ , which expresses the number of g. mols. of molybdic acid transformed per second in a unit cell of 1 cm.  $\times$  1 cm.  $\times$  1 cm.  $I_{\text{abs}}$  represents the intensity of radiation (366  $\mu$ ) absorbed in Einsteins per sq. cm. per sec. by a column of solution of 1 cm. thickness.

It will be noticed that the velocity of reduction is maximum when  $\text{MoO}_3$  and  $\text{H}_2\text{T}$  are equimolecular in concentration, and it decreases on both sides of this ratio. The colour of the reduction product changes from deep blue when  $[\text{MoO}_3] > [\text{H}_2\text{T}]$  to pale yellow when  $[\text{MoO}_3] < [\text{H}_2\text{T}]$ .

The effect of  $p_{\text{H}}$  on the reduction rate of different mixture of  $\text{MoO}_3$  and  $\text{H}_2\text{T}$  has been studied and the results are given in Table II below.

TABLE II

Compn. of the mixture in $M \times 10^3$	$p_{\text{H}}$	$dx/dt \times 10^4$	$k_0 \times 10^{11}$	$I_{\text{abs}} \times 10^{11}$	$\nu$
2.60 $\text{MoO}_3$ 0.65 $\text{H}_2\text{T}$	2.29	33.3	7.42	35.95	0.20
"	3.46	26.6	5.93	33.43	0.18
"	6.14	5.0	1.11	18.27	0.06
"	7.50	1.0	0.22	4.86	0.05
2.60 $\text{MoO}_3$ 1.30 $\text{H}_2\text{T}$	2.09	46.6	10.39	34.40	0.30
"	3.99	36.6	8.16	31.49	0.41
"	6.18	5.0	1.11	21.82	0.05
"	7.83	0.5	0.11	4.47	0.02
2.60 $\text{MoO}_3$ 5.21 $\text{H}_2\text{T}$	1.82	33.3	7.42	19.24	0.39
"	2.56	26.6	5.86	18.65	0.31
"	5.87	8.6	1.92	12.82	0.15
"	7.21	0.9	0.21	4.47	0.04
2.60 $\text{MoO}_3$ 10.43 $\text{H}_2\text{T}$	1.75	26.6	5.93	13.80	0.43
"	2.71	20.7	4.62	11.66	0.40
"	6.15	6.6	1.47	10.50	0.14
"	7.75	1.0	0.22	4.08	0.05

It will be noticed in the above table that  $p_{\text{H}}$  values of the systems have an appreciable influence on the rate of reduction and it is remarkable that above  $p_{\text{H}}$  5.0, the values of  $dx/dt$  rapidly diminish. It is also to be noted that the quantum efficiency of the process is much less than unity in all cases.

The influence of reduction on the optical rotatory power of the complex molybdotartaric acid solution is represented in Table III.

TABLE III

Compn. of the the mixtures in $M \times 10^4$ .	*Amount of reduction.	Observed rotations at wave-lengths											
		690 $\mu\mu$			578 $\mu\mu$			546 $\mu\mu$			436 $\mu\mu$		
		(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
2.36 $\text{MoO}_3$ 0.57 $\text{H}_2\text{T}$	2.01	+0.10	(-)	+0.09	+0.13	(-)	+0.13	+0.17	(-)	+0.16	+0.34	(-)	+0.32
2.36 $\text{MoO}_3$ 1.14 $\text{H}_2\text{T}$	2.61	+0.021	(-)	+0.20	+0.26	(-)	+0.25	+0.31	(-)	+0.30	+0.54	(-)	+0.50
2.36 $\text{MoO}_3$ 2.36 $\text{H}_2\text{T}$	5.40	+0.88	+0.36	+0.36	+0.48	+0.44	+0.43	+0.55	+0.50	+0.49	+1.05	+1.05	+0.96
2.36 $\text{MoO}_3$ 4.68 $\text{H}_2\text{T}$	3.84	+0.55	+0.54	+0.56	+0.71	+0.70	+0.68	+0.79	+0.77	+0.75	+1.57	+1.58	+1.54
2.36 $\text{MoO}_3$ 9.37 $\text{H}_2\text{T}$	2.10	+0.71	+0.72	+0.70	+0.90	+0.87	+0.87	+1.01	+0.97	+0.95	+1.90	+1.80	+1.81

\* "Amount of reduction" is expressed in terms of c.c. of 0.6688N- $\text{KMnO}_4$  solution per 10 c.c. of the reduced solution.

Suffix (1) represents rotation values before reduction.

" (2) " " after reduction.

" (3) " " after titration of the reduced mixture with  $\text{KMnO}_4$  solution to reproduce the original oxidant.

The rotation values corresponding to the mark (-) could not be measured due to the intense blue colour of the solution; but after titration with  $\text{KMnO}_4$  solution it was possible to measure them because the reduced solution became colourless at the end-point. The observed rotation values are corrected for dilution caused by the addition of the titre and noted in the table. It will be seen that there is no appreciable increase or decrease of rotation values caused by the reduction.

## DISCUSSION

Addition of  $\text{H}_2\text{T}$  to pure  $\text{MoO}_3$  sol exposed to ultraviolet makes it very susceptible towards reduction. The cause of this reduction superficially indicated by some is due to complex formation. But Ghosh and collaborators (*loc. cit.*) assumed the formation of active centres on colloid surface. Following the observations of Jander and others (*Z. anorg. Chem.*, 1930, 194, 413) that aggregates of different compositions of  $\text{MoO}_3$  are formed at different  $p_H$  of the sol, they explained the observed different reduction velocity at different  $p_H$  on the assumption that micelles of different compositions differed in their photo-activity.

It has been observed in our case that reduction takes place in a system where there is no free or uncombined  $\text{H}_2\text{T}$  present (*i.e.* when  $[\text{MoO}_3] \geq 4 [\text{H}_2\text{T}]$ ) according to our observation in Part I, Biswas, *J. Indian Chem. Soc.*, 1945, 22, 351) and also where there is no colloidal particles present, all the solutes being apparently present in true solution (*i.e.*, when  $[\text{H}_2\text{T}] \geq 4 [\text{MoO}_3]$  according to our observations in Part III, *ibid.*, 1946, 23, 257). The reaction is obviously going through some other mechanisms and we have advanced here a plausible conception by which all the observed facts can be explained.

The application of the concept of "stabilisation of valences by co-ordination" can explain all the observed facts. It is well known that the oxidation-reduction potential of ions is greatly altered through the formation of complex ions of varying stability. This often leads to a stabilisation of valency of the element in question in higher or lower states of oxidation. From among many such known examples may be cited the addition of pyridine or thiocyanate ions into nickel (ous) chloride and cobalt (ous) chloride, both of which form strongly co-ordination compounds and this increases the ease with which nickel and cobalt ions are reduced (Lingane and Kerlinger, *Ind. Eng. Chem. Anal. Ed.*, 1941, 13, 77). Probably molybdic acid is similarly stabilised at lower state of valency by forming a co-ordination compound with  $H_2T$  and hence it becomes susceptible towards reduction, slowly in the dark and rapidly in the ultraviolet, by capturing electrons from the surroundings or making some other suitable rearrangement within the molecule itself.

The course of reduction probably proceeds thus : The complex molecule  $H_2(MoO_3T, H_2O)$  and its ions are first reduced but free molybdic acid, when present in the mixture, takes away the acquired electron from the complex and is itself reduced probably to  $Mo_2O_3$  or some other product which has a blue colour. The complex thus, acts like a catalyst transferring its acquired electron to its neighbour so long as un-reduced free  $MoO_3$  is present. After that the reduction of the complex itself goes on and its rate of reduction becomes slower than the above process.

Accordingly the velocity of reduction depends on the concentration of both free  $MoO_3$  and the complex in a mixture and an optimum proportional concentration of the two to show maximum reaction velocity is attained when  $MoO_3$  and  $H_2T$  are present in equimolecular proportion (Table I)

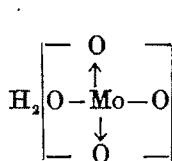
The colour of the reduction product from blue to yellow (Table I) can be accounted thus : The colour of reduced  $MoO_3$  is blue and that of the complex is pale yellow. When the  $[MoO_3]$  is much greater than  $[H_2T]$ , the colour of reduced  $MoO_3$  predominates, but when  $[H_2T]$  is preponderating, the colour of the reduced complex predominates and in intermediate stages the observed colour is the mixture of the two extremes.

The variation of reduction velocity with  $p_H$  can be explained on the assumption that the unionised molecule  $H_2(MoO_3T, H_2O)$  is more easily reduced than its ions and so reduction velocity decreases with increase of  $p_H$ . But above  $p_H$  5.0, the rapid drop in velocity to a very low figure (Table II) is due to the fact that the complex begins to dissociate into its components above  $p_H$  4.2 (as shown in part II, Biswas, *ibid.*, 1946, 23, 249) when the concentration of the complex rapidly decreases and the component molybdate ion as itself has little tendency to reduction.

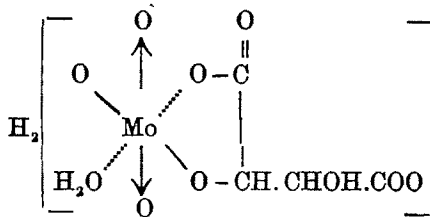
The application of the electronic theory of valency also reflects the relative instability of the complex as depicted before.

Sidgwick ("The Electronic Theory of Valency", p. 163, Oxford University Press, London, 1927) has suggested that the stable valency groups are formed when the "effective atomic number" of the central atom is equal to that of an inert gas. On this basis the marked stability of  $Mo(CN)_6^{IV}$  present in aqueous solution of the complex

salt  $K_4[Mo(CN)_6]$  can be readily appreciated when it is seen that the E. A. N is 54, similar to the inert gas xenon. If we apply the same to the case of molybdic acid (I) and complex molybdotartaric acid (II)



(I)



(II)

we find that the E. A. N's are 46 and 50 and they are short of 8 and 4 electrons respectively to attain the structure of xenon. Accordingly they should be unstable as is actually observed by their readiness to reduction.

That the complex molybdotartrate does not break up by reduction into components and probably some sort of rearrangement only takes place in the complex, is indicated by the fact that the rotation values of different reduced mixtures (Table III) are not appreciably different from the respective parent solutions, and hence we can say that the reduced solution contains a similar complex of optical rotatory power nearly equal to that of the parent complex compound.

My best thanks are due to Sir J. C. Ghosh for his kind interest in this work.

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# STUDIES ON REACTIONS OF SULPHONAZIDES WITH PYRIDINE

## PART I. SALTS AND DERIVATIVES OF PYRIDINE-IMINE

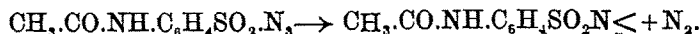
By P. K. DATTA

*p*-Acetylaminobenzene sulphonazide and *p*-toluene sulphonazide were respectively heated with excess of pyridine. The main reaction products were proved respectively to be *p*-acetylaminobenzene sulphon-N-iminopyridine and *p*-toluene sulphon-N-iminopyridine. These substances were hydrolysed and different salts and derivatives of N-iminopyridine were prepared. The free base N-iminopyridine was also liberated, but found to be quite unstable. The N-iminopyridine structure has finally been confirmed by *total* synthesis.

In course of studies on the reaction of sulphonazides, Curtius and Kraemers (*J. prakt. Chem.*, 1930, 125, 323) heated *p*-toluene sulphonazides with pyridine and isolated a crystalline compound ( $C_{12}H_{11}O_2N_2S$ , m. p. 210°). They supposed it to be *p*-toluene sulphonamidopyridine. The base, remaining after removal of *p*-toluene sulphonic acid by hydrolysis, formed a picrate, m. p. 138-39°. But this melting point of the picrate did not agree with the m. p. of any of the picrates of known aminopyridines. Though they called this base an aminopyridine, they were not definite about its exact structure. Moreover, the reactions of this compound, as described by them, are quite different from those expected from the three known aminopyridines.

In the present communication, the detailed study of the action of different sulphonazides on pyridine is described.

In the first instance, *p*-acetylaminobenzene sulphonazide (Curtius, *J. prakt. Chem.*, 1926, 112, 128) has been heated at about 150° for 30 hours with five times its weight of pyridine in a  $CO_2$  atmosphere and the evolved gas collected. The gas is found to be nitrogen and forms 92% of the amount required by the equation :



During the course of reaction yellowish white crystalline incrustation is formed. After repeated crystallisations, the substance melts with decomposition at 284°, the yield being very small.

From the reaction mixture a number of different substances has also been isolated. Their structure and properties will be published in subsequent communications.

The reaction does not take place at lower temperature. Even at 100°, no nitrogen is found to evolve and the azide is recovered unchanged after distillation of pyridine in vacuum. Moreover, the reaction cannot be completed in a shorter time as some unchanged azide is found to remain even after heating at 150° for 11 hours. Reduction of the quantity of pyridine to twice the amount of the azide also leads to an explosion of the azide.

Estimation of C, H, N and S of the substance of m. p. 284° shows that it has the empirical formula  $C_{13}H_{15}O_3N_3S$ . This is insoluble in pyridine, alcoholic and aqueous



caustic solutions, even at a slightly elevated temperature. Diazo reaction for primary amino group is found negative at first, but on mild hydrolysis with dilute hydrochloric acid, the diazo reaction is positive.

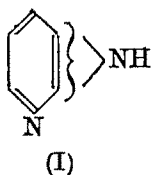
The hydrolysed product is beautifully crystalline, m. p.  $228.5^{\circ}$ . Estimations of C, H, N and molecular weight show that it has the formula  $C_{11}H_{11}O_2N_3S$ , of which one of the nitrogen forms the part of an aromatic primary amino group. Hence the formula can be written as  $NH_2\{C_{11}H_9O_2N_2S\}$

Estimation of Pt in the platonic chloride derivative (m. p.  $224^{\circ}$ ) indicates the formula  $\{C_{11}H_{11}O_2N_3S\}, H_2PtCl_6$  showing that it has two basic groups. Evidently the amino group is one of the basic groups, while the other must be contained in the  $(C_{11}H_9O_2N_2S)$ -residue.

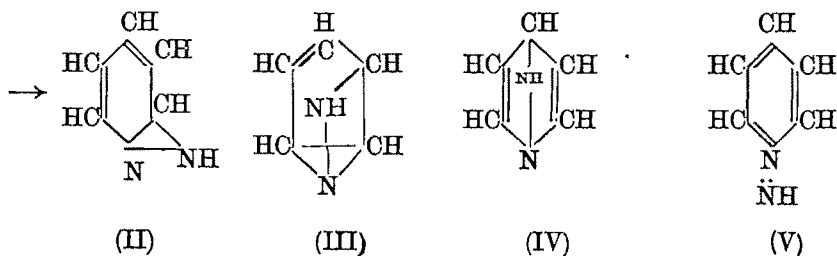
The substance of m. p.  $228.5^{\circ}$  can be further hydrolysed by heating with concentrated hydrochloric acid to sulphanilic acid and hydrochloride of a base. The latter can be easily converted into a perchlorate (m. p.  $204^{\circ}$ ). Analytical data and molecular weight determination indicate its formula as  $C_6H_6N_2.HClO_4$ .

Hence the formula  $C_{11}H_{11}O_2N_3S$  may be expanded to  $NH_2.C_6H_4.SO_2\{C_5H_5N_2\}$  which by the addition of a molecule of water, during hydrolysis, produces  $NH_2.C_6H_4SO_3H$  and  $C_5H_6N_2$ . The base  $C_5H_6N_2$  is extremely unstable in the free state, but quite stable as salts and derivatives.

By the action of nitrous acid on the perchlorate of the base in the cold, nitrogen is evolved and pyridine is obtained in the solution which is identified as pyridine perchlorate. So the base may be represented as (I) which contains a pyridine nucleus.

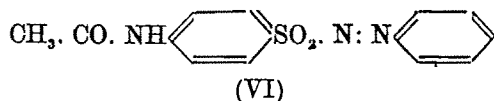


Alkaline ferriecyanide is also found to liberate half the amount of nitrogen from the perchlorate of the base. The base is quite different from any of the three aminopyridines. Now, if the additional nitrogen be attached to any two carbon atoms of the pyridine ring, then a cyclic polymethylene-imine ring would result. But this type of ring systems is quite stable to oxidising agents and no evolution of nitrogen occurs (Howard and Marckwald, *Ber.*, 1899, 32, 2036). Moreover, there would result a di-acidic base, but this compound is a mono-acidic base, as is evident from the analytical data of its picrate, perchlorate and platinichloride. The additional nitrogen atom may be attached directly to the nitrogen atom of the pyridine ring. Then the base must have the structure (II) (III), (IV), or (V).

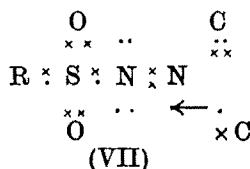


By exhaustive hydrogenation of the base-hydrochloride with palladium-charcoal catalyst in alcoholic suspension, piperidine is obtained, and identified as its perchlorate. In course of this hydrogenation 8 atoms of hydrogen per molecule are taken up.

By partial hydrogenation of the compound  $C_{11}H_{11}O_2N_3S$  (m. p. 228.5°) by palladium-charcoal in acetic acid suspension, acetylsulphanilamide and pyridine are obtained and identified. During this course, 2 atoms of hydrogen are allowed to be taken up. These findings can only be explained if the base *have* structure (V); otherwise in structures (II), (III), or (IV), *only* 4 atoms of hydrogen per molecule can be taken up in the exhaustive hydrogenation and the product of hydrogenation would have been quite different. Hence the structure of the compound  $C_{11}H_{11}O_2N_3S$  must be represented by (VI).



From the consideration of the adjustment of electrons in the compound (VI), it is evident that the nature of the linkage between the two nitrogen is of the semipolar-double-bond type, in which case the ring nitrogen (VII) acts as a donor

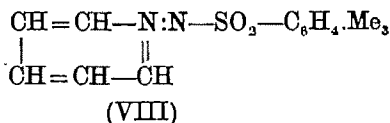


and the extra nitrogen as an acceptor. This is also quite in agreement with the mono-acid character of the base.

Similar type of linkage was also predicted to exist between nitrogen and oxygen in the case of pyridine-N-oxide and quinoline-N-oxide (Meisenheimer, *Ber.*, 1926, 59, 1848). Schneider also reported a few compounds obtained by the action of phenylhydrazine on substituted pyryllium salts (*Annalen*, 1924, 433, 115; *cf. Chem. Rev.*, 1944, 35, 92). His coloured anhydro-bases were supposed to have a grouping  $\equiv N = N -$ , which he accounted for the production of colour.

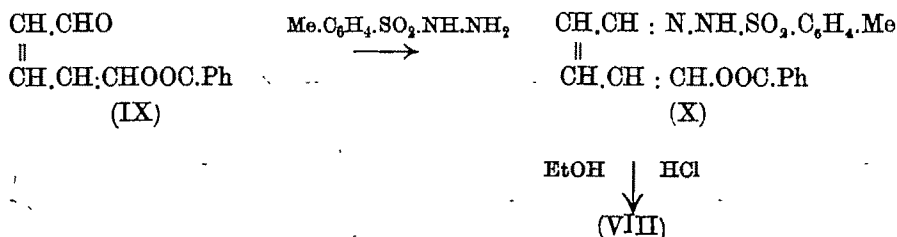
The work of Curtius and Kraemers (*loc. cit.*) with *p*-toluene sulphonazide and pyridine has been repeated in absence of air. The reaction product after crystallisation from alcohol has a m. p. 210° as mentioned by the original authors. The base-hydrochloride obtained by hydrolysis of this compound (m. p. 210°) is found

to be identical with the base-hydrochloride obtained from *p*-acetylaminobenzene sulphonimidopyridine compound. Other derivatives of the base viz., perchlorate, picrate and platinichloride are also found to be identical with those of the previous one. This has further been confirmed by allowing *p*-acetylaminobenzene sulphochloride to react on this base (from the *p*-toluene compound) which leads to the production of compound (VI). Hence the Curtius-Kraemer compound of m. p. 210° must have the structure (VIII).



The N-iminopyridine structure has further been confirmed by the direct synthesis of the compound (VIII.)

Monobenzoyl derivative of glutaconic dialdehyde (IX) is obtained from pyridine (Baumgarten, *Ber.*, 1924, **B**, 57, 1625) and condensed with *p*-toluene sulphonhydrazide. The compound (X) suffers ring-closure with the elimination of ethyl benzoate. The substance obtained after neutralisation is found identical with the compound (VIII) obtained by Curtius process.



Further investigations about this interesting class of compounds are in progress.

#### EXPERIMENTAL

*Reaction of p-Acetylaminobenzene sulphonazide with Pyridine.*—Pure and dry *p*-acetylaminobenzene sulphonazide (30 g.) was heated under reflux with freshly distilled pyridine (150 g.) at 150° in a metal-bath. The apparatus was connected to a nitrometer, filled with 50% caustic potash and the air in the system was replaced by a slow stream of dry carbon dioxide. Heating was continued in the CO<sub>2</sub>-atmosphere for 30 hours until no more nitrogen evolved. Total nitrogen evolved was 2914 c.c. at 30°/760.2 mm. A hard, crystalline, yellowish white incrustation was formed inside the vessel. This was separated from the main reaction mixture by filtration. The substance is sparingly soluble in alcohol and water, more soluble in acetic acid and also in dilute hydrochloric acid. It was repeatedly crystallised from alcohol and finally crystallised from dilute acetic acid and obtained as yellowish white, highly refracting prismatic crystals, m.p. 284° (decomp.), yield 5.2 g. (This is referred in this paper as compound A).

(Found : C, 53.62 ; H, 4.14 ; N, 14.18 ; S, 10.61.  $C_{13}H_{13}O_3N_3S$  requires C, 53.6 ; H, 4.47 ; N, 14.43 ; S, 11.0 per cent).

The dark brown mother-liquor after separation of the compound (A) was distilled in vacuum and from the tarry residue a number of different substances was obtained.

*Deacetylation of Compound (A).*—Compound (A) (2.9 g.) was suspended in alcohol and the mixture was saturated with hydrochloric acid gas in cold, when most of the suspensions went into solution. The solution was allowed to stand in a refrigerator for 24 hours when large, cubic, hygroscopic crystals separated out which were collected. The filtrate, which strongly smelled of ethyl acetate and hydrochloric acid was concentrated in vacuum and a further crop of crystals was obtained. The crystals were collected, dissolved in water and just neutralised with sodium carbonate, when the amino compound (compound B) precipitated. The substance was crystallised from absolute alcohol (charcoal) as fine, light yellow crystals, m. p.  $228.5^\circ$ , yield 2.3 g. It is insoluble in water. (Found : N, 16.54.  $C_{11}H_{12}O_2N_3S$  requires N, 16.86 per cent).

The substance can be diazotised and coupled with alkaline  $\beta$ -naphthol with the production of beautiful red colour.

*Platinichloride derivative of compound (B)* was prepared in the usual way and after crystallisation from dilute hydrochloric acid (0.1N) melted at  $224^\circ$ . (Found : Pt, 30.01.  $C_{11}H_{11}O_2N_3S \cdot H_2PtCl_6$  requires Pt, 29.65 per cent).

*Complete Hydrolysis of compound (B).*—The substance (2.4 g.) was heated with concentrated hydrochloric acid (30 c. c.) for 5 hours under reflux. The resulting solution was concentrated under vacuum to about 10 c.c. and then cooled to  $0^\circ$ . The crystals were filtered off and washed with ice-water. The filtrate and washings were again concentrated in vacuum to about 3 c.c., cooled and the crystals were filtered off, yield 1.61 g. It proved to be sulphanilic acid by the usual tests and also by converting it into 1:3:5-tribromoaniline, m. p.  $119^\circ$ .

The filtrate was decolourised by animal charcoal and concentrated in vacuum. The hydrochloride of a base (compound C) was obtained as colourless, long crystals. It is extremely hygroscopic and also highly soluble in methyl and ethyl alcohol. It gives a violet coloration with alkali, and a red coloration with alkaline nitroprusside.

*Perchlorate of compound (C)* was obtained from an alcoholic solution of the hydrochloride of compound (C) (0.2 g.) and perchloric acid solution (1 c. c., 70%) as fine white crystals. It crystallised from absolute alcohol, m. p.  $204^\circ$ , yield 0.17 g. It gives a violet coloration with alkali and a red coloration with alkaline nitroprusside. [Found: N, 14.14 ; M. W. (by freezing point method in water), 190.  $C_5H_6N_2$ ,  $HClO_4$  requires N, 14.39 per cent. M. W., 194.5).

*Picrate of Compound (C).*—A methyl alcoholic solution of the hydrochloride of compound (C) (0.5 g.) was added to a suspension of freshly prepared silver oxide (1 g.) in methyl alcohol in cold. The mixture was rapidly shaken and immediately filtered. The filtrate was immediately added to a saturated solution of picric acid in

methyl alcohol (5 c. c.) in cold. After a few hours' standing in cold, the picrate was filtered off, and washed with a little cold methyl alcohol. It crystallised from methyl alcohol as orange plates, m. p. 149°. (Found: N, 21.92.  $C_{11}H_9O_7N_3$  requires N, 21.66 per cent).

By keeping a bit longer in presence of silver oxide, silver oxide was reduced to silver even in cold and the solution became deep violet in colour. From this solution no picrate could be obtained.

*Patinichloride of compound (C)* crystallised from dilute hydrochloric acid (0.1N) as long, golden yellow plates, m. p. 237° (decomp.). [Found: Pt, 32.93.  $(C_5H_6N_2)_2, H_2PtCl_6$  requires Pt, 32.62 per cent].

*Action of Nitrous acid on Perchlorate of Compound (C).*—The perchlorate (0.2 g.) was dissolved in water (5 c. c.) and to this perchloric acid (70% 0.5 c. c.) was added. Then a solution of potassium nitrite (0.1 g. in 2 c. c.) was added in cold and left for 12 hours. The solution was evaporated in vacuum and treated with alcohol. The potassium perchlorate was filtered off and from the filtrate a perchlorate was obtained, m. p. 282° (mixed m. p. with pyridine perchlorate).

*Action of Alkaline Ferricyanide on Perchlorate of Compound (C).*—Aqueous solution of the perchlorate (0.201 g. in 20 c. c. water) was taken in a three-necked flask (100 c. c.), the necks of which were respectively connected to (i) a  $CO_2$ -Kipp's apparatus, (ii) a dropping funnel with drawn end and (iii) a nitrometer, filled with 50% KOH solution. The air in the flask was completely chased out by a slow stream of  $CO_2$ . Then an alkaline solution of potassium ferricyanide was slowly introduced into the flask and it was slightly warmed on a water-bath. The gas measured 12.70 c. c. at 29.5°/759.5 mm.

A parallel blank experiment was also performed and the gas evolved was negligible (0.05 c. c. at 29.5°/759.5 mm.).

*Liberation of Compound (C) from its Perchlorate.*—The perchlorate (0.4141 g.) was dissolved in absolute alcohol (30 c. c., free from aldehyde) and cooled in a freezing mixture. Then freshly prepared alcoholic potash (15 c. c. of 0.1355N; 15.97 c. c. actually required) was added slowly. The mixture was kept at 0° for 12 hours and rapidly filtered in cold. The solution was violet in colour and had a strong basic odour. The alcohol was distilled off at low temperature in vacuum. A deep violet scaly substance with a strong basic odour was obtained. It is soluble in water, benzene, alcohol, ether and chloroform. The violet colour of the solution is discharged on acidification. The substance rapidly transformed into a black resinous matter at room temperature, even in vacuum or in solution, and the solubility as well as other properties were lost after this transformation.

*Catalytic Hydrogenation of Hydrochloride of Compound (C).*—A solution of the hydrochloride (0.201 g.) in ethyl alcohol (20 c. c.) and fused sodium acetate (0.15 g.) were shaken with 0.2 g. of 10% palladium-charcoal catalyst (which had been previously saturated with hydrogen) in an atmosphere of hydrogen. 155 C. c. of hydrogen at 30°/759 mm. were absorbed within 3 hours.  $(C_5H_6N_2)$  requires 153.3 c. c. at 30°/759 mm.)

The solution was filtered and the solvent concentrated in vacuum. Perchloric acid solution (5 drops) was added, the solution cooled and the crystals filtered off and recrystallised as fine white crystals, m. p. 129° (mixed m. p. [with piperidine perchlorate]).

*Catalytic Hydrogenation of Compound (B).*—A solution of compound (B) (0.25 g.) in glacial acetic acid (25 c. c.) was shaken with 0.2 g. of 10% palladium-charcoal catalyst (which had been previously saturated with hydrogen) in an atmosphere of hydrogen. The shaking was stopped when 25 c. c. of hydrogen at 30°/759 mm. had been absorbed ( $C_{11}H_{11}O_2N_3S$  requires 24.8 c. c. of hydrogen at 30°/759 mm.). The solution was filtered off, and the solvent removed in vacuum. The residue was treated with water (10 c. c.) and the crystals filtered off. After crystallisation from water, the substance was obtained as fine, white needles, m. p. 219° (mixed m. p. with  $N^4$ -acetyl-sulphanilamide).

The filtrate was acidified with a few drops of perchloric acid, concentrated in vacuum and treated with alcohol. A white perchlorate was obtained which after crystallisation had a m. p. 282° (mixed m. p. with pyridine perchlorate).

*Repetition of Curtius-Kraemers Reaction*—*p*-Toluene sulphonazide (20 g.) was heated with pyridine (150 c. c.) in absence of moisture and air, in a  $CO_2$  atmosphere. The heating was continued for 30 hours at 130°. The solid reaction product was filtered off and was obtained as fine, white crystals (compound D), m. p. 210°, yield 7.9 g. (same as mentioned by original authors).

The substance (5 g.) was hydrolysed by heating with concentrated hydrochloric acid (30 c. c.) in a sealed tube for 12 hours at 135°. The crystals were filtered and proved to be *p*-toluene sulphonic acid. The filtrate was decolorised by animal charcoal, filtered, and evaporated in vacuum. The hydrochloride (compound E) was obtained as extremely hygroscopic long plates. It gave a violet coloration with alkali and a red coloration with alkaline nitroprusside.

The perchlorate was obtained from the hydrochloride (compound E), and had a m. p. 204° (mixed m. p. with perchlorate from compound C).

The platinichloride melted at 237° (mixed m. p. with the platinichloride of compound C).

The picrate melted at 149° (mixed m. p. with the picrate of compound C).

*Reaction of Compound (E) with p-Acetylaminobenzene sulphochloride.*—To an aqueous solution of 0.26 g of the hydrochloride (compound E), cooled to 0°, was added slowly and simultaneously *p*-acetylaminobenzene sulphochloride (0.4 g.) and 10% sodium hydroxide solution (1.6 c. c.) with rapid and constant stirring. After 1 hour, the white precipitate was filtered off, washed with cold water and alcohol. After crystallisation from alcohol and acetic acid, the substance was obtained as prismatic crystals, m. p. 284° (decomp.), mixed m. p. with *p*-acetylaminobenzene sulphonimido-pyridine (compound A, m. p. 284°, decomp.).

*Total Synthesis of Compound (D), (VIII).*—Monobenzoyl derivative of glutamic dialdehyde (IX), prepared from pyridine (Baumgarten, *loc cit.*) was dissolved in dry ether and to this solution was added an ethereal solution of *p*-toluene sulphonyl-

zide (1.9 g. Curtius, *J. prakt. Chem.*, 1930, 125, 323) and left in cold for 3 days. Light yellow crystals began to separate, which were filtered off. A further crop of crystals was obtained on removal of the ether. The crystals were collected and recrystallised from methyl alcohol as light yellow scales, yield 2.1 g. (Found: N, 7.96.  $C_{14}H_{18}O_4N_2S$  requires N, 8.22 per cent).

The hydrazone (1 g.) was dissolved in absolute alcohol (20 c. c.) and to this was added 2 c. c. of alcoholic hydrochloric acid (saturated at 25°). The solution was warmed at 45° for 3 hours, when smell of ethyl benzoate was obtained. The solution was concentrated in vacuum and ether (10 c. c.) was added. The crystals were filtered off, washed with ether and dissolved in minimum amount of water. The solution was neutralised with potassium carbonate and the precipitate was filtered off and washed with water. After crystallisation from alcohol the substance had a m. p. 310° (mixed m. p. with Curtius Kraemer's compound obtained from *p*-toluene sulphonazide)

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# STUDIES ON THE CIRCULAR DICHROISM AND ROTATORY DISPERSION. PART II. ANALYSIS OF THE CURVES OF CIRCULAR DICHROISM AND ROTATORY DISPERSION OF AMMONIUM VANADYL *d*-TARTRATE

By B. C. KAR

In a previous paper (*J. Indian Chem. Soc.*, 1945, 22, 278) the author has measured the circular dichroism and rotatory dispersion of ammonium vanadyl *d*-tartrate. The curves of circular dichroism and rotatory dispersion in the region of absorption have been analysed. The circular dichroism can be represented by the equation of Kuhn and Szabo (*Z. physikal. Chem.*, 1931, B, 16, 59) which is

$$(\epsilon_l - \epsilon_r) = (\epsilon_l - \epsilon_r)_{\max} e^{-\left(\frac{\nu_0 - \nu}{\theta}\right)^2}$$

where  $(\epsilon_l - \epsilon_r)_{\max}$  is the maximum circular dichroism corresponding to the frequency  $\nu_0$ , the parameter  $\theta$  is related to the half-width of the band of circular dichroism by the relation  $\nu$  (half-width) = 1.6652  $\theta$ . The rotatory dispersion can be represented by the equation of Kuhn and Braun (*ibid.*, 1930, B, 8, 281) which is

$$[M] = \frac{100}{2\sqrt{\pi}} \frac{(\epsilon_l - \epsilon_r)_{\max}}{\log_{10} e} \frac{\nu}{\nu_0} \left[ e^{-\left(\frac{\nu_0 - \nu}{\theta}\right)^2} \int_0^{\frac{\nu_0 - \nu}{\theta}} e^{-x^2} dx - \frac{\nu}{2(\nu_0 + \nu)} \right]$$

where  $[M]$  is the molecular rotatory dispersion for a length of the solution 1 cm. and the other symbols have the same significance as before. The discrepancies between the experimental and theoretical values have been explained and also the merit of the equation of Kuhn and Braun in explaining rotatory dispersion in absorbing media.

A method of preparing ammonium vanadyl *d*-tartrate and of measuring the absorption, circular dichroism and rotatory dispersion in the visible region was given by the author in the previous part (*J. Indian Chem. Soc.*, 1945 22, 278). In this communication an attempt has been made to explain the results.

From the ellipticity, circular dichroism was calculated by the relation,

$$(\epsilon_l - \epsilon_r) = \frac{4 \log_{10} e \phi}{c.l.}$$

where  $\epsilon_l$  and  $\epsilon_r$  are the molecular extinction coefficient for *l* and *r* light; *c* is the molar concentration, *l* is the length in centimetre,  $\phi$  is the ellipticity expressed in radians. If  $\phi$  is expressed in degrees, we have

$$(\epsilon_l - \epsilon_r) = \frac{4 \times 0.4343 \times \phi}{0.1 \times 0.5 \times 57.296}$$

These observed values of  $(\epsilon_l - \epsilon_r)$  are given in Table I against the respective wave-lengths. The values  $(\epsilon_l - \epsilon_r)$  for the first absorption band are then plotted against frequency  $\nu$  in Fig. 1 to get the experimental curve of circular dichroism. The corresponding graph for the second absorption band is obtained in Fig. 2.

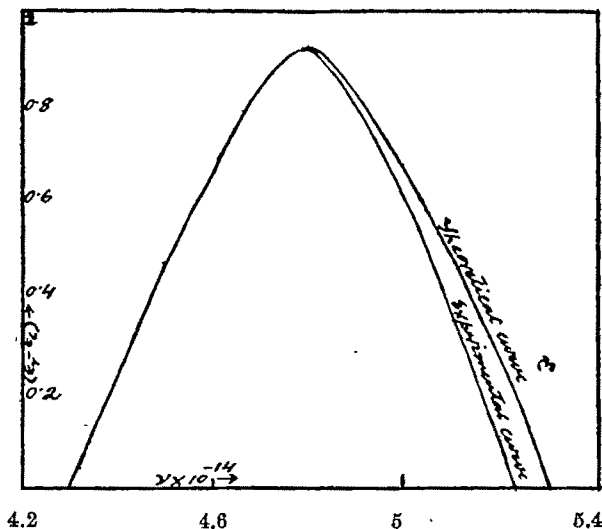
These curves of circular dichroism can be expressed to a very close approximation by means of the equation of Kuhn and Szabo,

$$(\epsilon_l - \epsilon_r) = (\epsilon_l - \epsilon_r)_{\max} e^{-\left(\frac{\nu_0 - \nu}{\theta}\right)^2}$$



$(\epsilon_l - \epsilon_r)_{\max}$  is the maximum value of the circular dichroism corresponding to the frequency  $\nu_0$ ,  $\nu'$  is the half-width of the band related to  $\theta$  according to the equation  $\nu' = 1.6652 \theta$ . This equation represents a curve which is symmetrical with respect to frequencies. The values of  $\nu_0$ ,  $\nu'$  and  $(\epsilon_l - \epsilon_r)_{\max}$ , as obtained from each curve, are set out in Table II. The half-width of the first curve is taken as twice the "semi-half width" as observed on the side of longer wave-length and the half-width of the second curve is similarly taken as twice the "semi-half width" in the shorter wave-length,

FIG. 1.



because the short wave-length side of the first curve and the long wave-length side of the second curve have been influenced one by the other with opposite circular dichroism. The calculated values of  $(\epsilon_l - \epsilon_r)$  according to the equation above and the corresponding curves of circular dichroism are given side by side in Table I and Figs. 1 and 2.

FIG. 2.

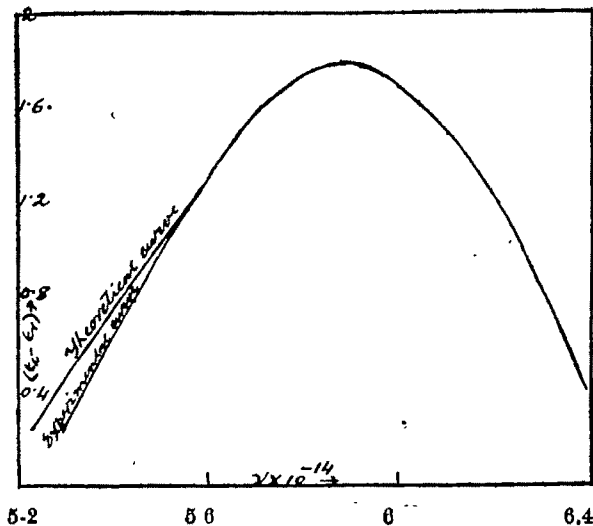


TABLE I

Concentration of ammonium vanadyl *d*-tartrate =  $M/10$ . $l = 5$  mm.

First circular dichroism curve				Second circular dichroism curve.			
$\lambda$ .	$\nu \times 10^{-14}$ .	$(\epsilon_i - \epsilon_r)_{\text{obs.}}$	$(\epsilon_i - \epsilon_r)_{\text{calc.}}$	$\lambda$ .	$\nu \times 10^{-14}$ .	$(\epsilon_i - \epsilon_r)_{\text{obs.}}$	$(\epsilon_i - \epsilon_r)_{\text{calc.}}$
6667Å	4.5	-0.46*	-0.46	5660Å	5.3	0.2304	0.4749
6500	4.615	-0.6852	-0.7068	5560	5.395	0.7398	0.7065
6438	4.66	-0.8487	-0.7912	5500	5.454	0.77	0.8726
6240 = $\lambda_0$	4.8 = $\nu_0$	-0.92*	-0.92	5494	5.46	0.89*	0.89
6200	4.839	-0.8913	-0.9093	5461	5.493	0.9581	0.9883
6000	4.999	-0.6972	-0.6782	5360	5.597	1.346	1.305
5900	5.084	-0.3759	-0.4944	5300	5.659	1.497	1.464
5893	5.1	-0.46*	-0.46	5200	5.769	1.595	1.696
5780	5.19	-0.1030	-0.2852	5100 = $\lambda_0$	5.88 = $\nu_0$	1.78*	1.78
				5000	5.999	1.637	1.684
				4916	6.102	1.534	1.469
				4800	6.25	1	1.04
				4762	6.3	0.89*	0.89

TABLE II

$\lambda_0$ in Å.	$\nu_0 \times 10^{-14}$ .	$(\epsilon_i - \epsilon_r)_{\text{max.}}$	$\nu' \times 10^{-14}$ .	$\theta \times 10^{-14}$ .
	(a) Parameters of first circular dichroism curve.			
6240	4.8	-0.92	0.6	0.3604
	(b) Parameters of second circular dichroism curve.			
5100	5.88	1.78	0.84	0.5034

\* Interpolated

*Analysis of the Curve of Rotatory Dispersion*

The experimental data for the measurement of rotatory dispersion for  $M/10$  concentration of ammonium vanadyl *d*-tartrate and length of the solution 5 mm. have been given in the previous paper (*J. Indian Chem. Soc.*, 1945, 22, 278). From the observed rotation, molecular rotation  $[M]$  was calculated by the relation  $[M] = 100\alpha/c$  where  $\alpha$  is the rotation per cm. column of the medium,  $c$  is the molar concentration. Therefore in this case

$$[M] = \frac{100 \times 2 \times \alpha_{\text{obs}}}{0.1}$$

It is obvious that this  $[M]$  is the algebraic sum of all the partial rotations due to different optically active absorption bands in the visible, ultraviolet and Schumann region for 1 cm. length of the column of the medium. These observed values of  $[M]$  are given in Table III and graphically represented against  $\lambda$  in Fig. 3.

An attempt has been made to analyse the curve of rotatory dispersion by means of the equation of Kuhn and Brann.

$$[M] = \frac{100}{2\sqrt{\pi}} \frac{(\epsilon_i - \epsilon_r)_{\text{max}}}{\log_{10} e} \cdot \frac{\nu}{\nu_0} \left[ e^{-\left(\frac{\nu_0 - \nu}{\theta}\right)^2} \int_0^{\frac{\nu_0 - \nu}{\theta}} e^{x^2} dx - \frac{\theta}{2(\nu_0 + \nu)} \right]$$

The symbols have the same significance as given before. The molecular partial rotations  $[M]_1$  and  $[M]_2$  for different wave-lengths for the two optically active absorption bands in the visible region are then calculated from the already determined values  $\nu_0$ ,  $\theta$  and  $(\epsilon_i - \epsilon_r)_{\max}$  as given in Table II. In making the calculations use is made of the table of values of the integral

$$e^{-c^2} \int_0^c e^{x^2} dx \left( c = \frac{\nu_0 - \nu}{\theta} \right)$$

for various values of  $c$ , as given by Kuhn (Freudenberg, "Stereochemie", Leipzig, 1932, p. 381). A graph was constructed by plotting  $c$  against Kuhn's values of the integrals and reading off the values of the integral for those values of  $c$  which correspond to the particular frequencies. For values of  $c$  greater than 3.2, the value of the integral

$$e^{-c^2} \int_0^c e^{x^2} dx$$

is taken approximately to be equal to  $1/2c$ .

In Table III are given these calculated partial rotations  $[M]_1$  and  $[M]_2$  due to the two absorption bands in the visible region and also their algebraic sum. In the last column of the table is given the difference between the total observed rotation and the algebraic sum of the calculated partial rotations. This difference evidently represents the residual rotation due to absorption bands in the ultraviolet and Schumann region. The algebraic sum of the calculated partial rotation and also the residual rotation are plotted in Fig. 3 and the respective curves obtained.

FIG. 3.

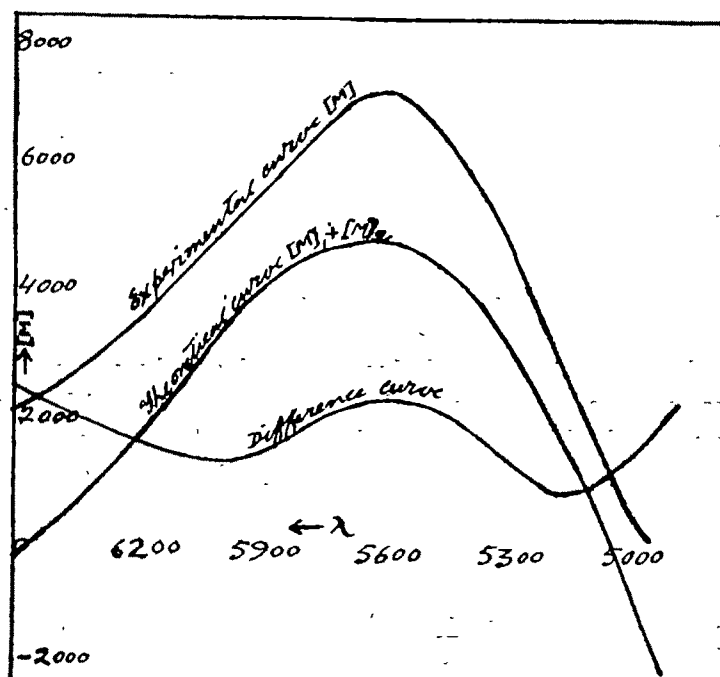


TABLE III

$\lambda$	$[M]$	$[M]_1$	$[M]_2$	$[M]_1 + [M]_2$	$[M] - [M]_1 + [M]_2$
		$\left\{ \begin{array}{l} (\epsilon_1 - \epsilon_2)_{\max} = -0.92 \\ \lambda_0 = 6240 \text{ \AA} \\ \rho_0 = 4.8 \times 10^{14} \\ \theta = 0.3604 \times 10^{14} \end{array} \right\}$		$\left\{ \begin{array}{l} (\epsilon_1 - \epsilon_2)_{\max} = 1.78 \\ \lambda_0 = 5100 \text{ \AA} \\ \rho_0 = 4.8 \times 10^{14} \\ \theta = 0.5034 \times 10^{14} \end{array} \right\}$	
6500Å	2100	-1376	1031	-345	2445
6438	2220	-1101	1095	-6	2226
6240	—	64.3	1352	1416	—
6200	3580	432.9	1443	1876	1704
6000	4860	1673	1898	3571	1289
5900	6000	1987	2191	4178	1822
5780	6440	2024	2582	4606	1834
5660	7040	1806	2948	4754	2286
5560	7040	1603	3141	4744	2296
5500	6800	1406	3158	4564	2236
5461	6520	1317	3116	4433	2087
5360	5520	1119	2735	3854	1666
5300	4200	1030	2315	3345	855
5200	2700	910.1	1236	2140	554
5100	—	820.4	-1418	678.6	—
5000	360	714.8	-1658	-943	1303
4916	100	674.8	-2799	-2124	2224
4800	160 ?	627	-3794	-3167	3327 ?

## DISCUSSION

The study of the circular dichroism and rotatory dispersion of ammonium vanadyl *d*-tartrate reveals the following characteristic features.

When ammonium vanadate  $(\text{NH}_4)\text{VO}_3$  is reduced with hydrobromic acid and the reduced salt is mixed with requisite amount of tartaric acid and neutralised with ammonia, a complex salt having the composition  $(\text{NH}_4)_2[(\text{VO})\text{H}_2\text{C}_4\text{O}_6] \cdot 2\text{H}_2\text{O}$  is obtained. The salt is very unstable and undergoes oxidation in presence of air. It has two optically active absorption bands in the visible region. Since circular dichroism cannot occur in a mixture in which the activity and absorption are due to different molecules, so it is evident that a complex is formed between tartaric acid and reduced vanadium salt and the optical activity and absorption are produced by the same molecule. The chromophoric groups which are responsible for the two absorption bands in the visible region and for optical activity due to induced dissymmetry are in the course of investigation.

The circular dichroism in these two bands are opposite in sign. The maximum circular dichroism  $(\epsilon_r - \epsilon_l)_{\max}$  of the first absorption band occurs at  $\lambda_0 = 6240 \text{ \AA}$  and the maximum circular dichroism  $(\epsilon_l - \epsilon_r)_{\max}$  of the second absorption band occurs at  $\lambda_0 = 5100 \text{ \AA}$ . Circular dichroism can be represented approximately by the expression

$$(\epsilon_l - \epsilon_r) = (\epsilon_l - \epsilon_r)_{\max} e^{-\left(\frac{\nu_0 - \nu}{\theta}\right)^2}$$

taking that the curve of circular dichroism is symmetrical with respect to frequencies since circular dichroism of the short wave length side of the first absorption band is complicated by opposite circular dichroism of the long wave-length side of the second absorption band. There is a better agreement between the experimental value and the theoretical value on the long wave-length side of the first absorption band and the short wave-length side of the second absorption band. The divergence between the theoretical and experimental values on the short wave-length side of the first absorption band and long wave-length side of the second absorption band is due to their mutual influence.

Within the region studied, it is found that the rotation gradually increases in the first absorption band, reaches a maximum on entering the second absorption band and then gradually decreases. The partial rotation due to both the bands in the visible region were calculated both inside the band where it is generated and outside it by the wellknown equation of Kuhn and Braun from the data on the measurement of circular dichroism. The sum of these two partial rotations clearly explains the above observation of the rotatory dispersion within the region studied, for the observed rotation is the algebraic sum of these two partial rotations and residual rotation which in this region may be taken to be normal. The usual characteristics of the anomalous rotatory dispersion associated with the first absorption band do not appear in our measurements as they all lie towards the longer wave-lengths which have not been studied.

The curve of difference in Fig. 3 represents the residual partial rotation due to bands in the ultraviolet and Schumann region, hence should be normal i. e. the rotation should increase progressively with decreasing wave-length but the experimental curve contains two loops one in the first absorption band and the other in the second absorption band. These loops are the conspicuous features of the curve of rotatory dispersion in the region of absorption. Since these loops are not completely eliminated, it indicates that the equation of Kuhn and Braun inadequately represents the partial rotations inside the absorption bands.

Similar observation was made by Lowry and Hudson (*Phil. Trans.*, 1933, **A** 232, 146) by studying the rotatory dispersion of xanthates and urethanes in the region of absorption.

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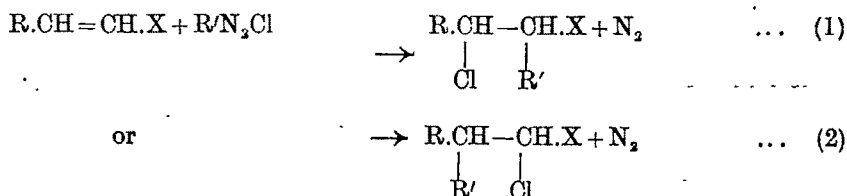
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# CONDENSATIONS OF ARYL DIAZONIUM SALTS WITH REACTIVE UNSATURATED COMPOUNDS. PART I. ACTION OF ARYL DIAZONIUM CHLORIDES WITH CITRACONIC AND MESACONIC ACIDS

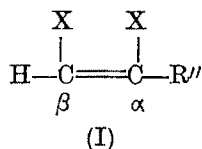
BY DEV RAJ DHINGRA AND KUNJ BEHARI LAL MATHUR

Aryl diazonium chlorides containing negative substituents react with citraconic acid and mesaconic acid in the presence of acetone, sodium acetate (buffer) and copper chloride to give  $\alpha$ -methyl- $\beta$ -aryl acrylic acids. The formation of the latter in place of the  $\beta\beta$ -isomer supports Koelsch's free radical mechanism for such condensations.

Aryl diazonium chlorides can react with  $\alpha\beta$ -unsaturated carbonyl compounds under certain conditions (Meerwein, Buchner and Emster, *J. prakt. Chem.*, 1939, 152, 237; Koelsch *et al.*, *J. Amer. Chem. Soc.*, 1943, 65, 57; 1944, 66, 412) to give products in which the aryl group and the chlorine atom first add on to the unsaturated linkage, thus



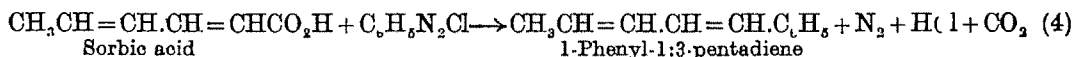
where X=COOR, COOH, CN, -CHO etc., depending upon the orienting influence of the group (R). The change occurs as in (1) if R is an unsaturated group *e. g.*, the vinyl and as in (2) if R is an alkyl group. These studies mostly relate to compounds containing only one activating group (X). Little is known about compounds which contain two such groups *e.g.*



In methyl ester of fumaric acid (I, R''=H; X=CO<sub>2</sub>Me) only one aryl addition product can result (Meerwein *et al.*, *loc. cit.*). But in other cases aryl addition may occur at the  $\alpha$  and/or  $\beta$  carbon atom according to the influence of the group R'' on the orienting capacity of one of the activating group (X) which would function like the unsaturated group (R) in (1). In the present investigation the action of certain aryl diazonium chlorides has been studied with citraconic and mesaconic acids (I, R''=Me; X=COOH) to ascertain the influence of the methyl group upon the position occupied by the aryl group in the reaction products with the acids.

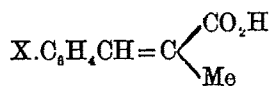
In case of a reaction going on as in (1), it is found that the elements of hydrogen chloride are usually lost during the course of the reaction. If the group (X) happens

also to be a COOH group, Meerwein, and Koelsch find that even carbon dioxide is lost and an unsaturated compound results :



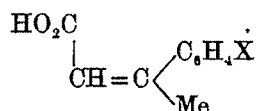
It was thought therefore that citraconic and mesaconic acids should in like manner give first an aryl unsaturated monobasic acid whose identity would settle the orientation possibilities as envisaged above. The reactions have therefore been done with the free acids rather than their esters in the sequel.

When *p*-nitro- and *p*-bromobenzene diazonium chlorides are reacted with citraconic acid in the presence of acetone, copper chloride and sodium acetate (*vide* experimental), nitrogen is briskly evolved and two solids result, from which aqueous sodium carbonate can extract out respectively the acids (A), m.p. 208° and (B), m. p. 173°, leaving behind neutral residues which do not show unsaturation. The gases evolved contain carbon dioxide, indicating decarboxylation during the reaction. These acids can possess either of the two following structures:



$\alpha$ -Methyl-*p*-nitro (or bromo) cinnamic acid.

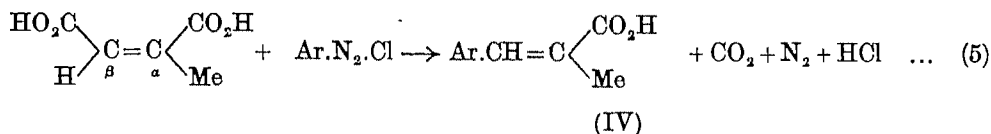
(II) (X = NO<sub>2</sub> or Br)



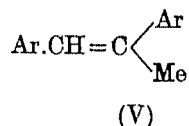
$\beta$ -Methyl- $\beta$ -nitro (bromo) phenylacrylic acid.

(III)

The identity of the two acids (A) and (B) with structure (II) has been shown by their respective syntheses from *p*-nitro or *p*-bromobenzaldehyde, sodium propionate and propionic anhydride. Diazonium chlorides from other amines react in the same way and give with citraconic acid, acids whose properties correspond to an  $\alpha$ -methyl- $\beta$ -arylacrylic acid (IV), which shows unmistakably the entrance of aryl group in the  $\beta$ -position, thus



No trace of the  $\beta$ -methyl- $\beta$  arylacrylic acid (type III) is detected. Further, the fact that in no case the neutral residue gives evidence for the presence of stilbene *e. g.*,

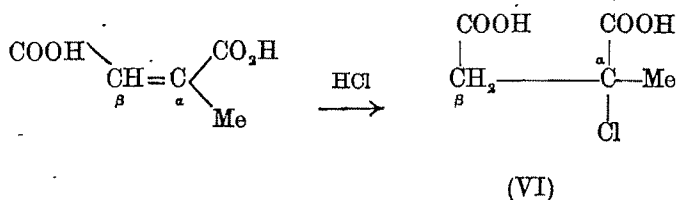


suggests that the rate of further condensation of the diazonium chloride with the acid (IV) is negligible compared to its primary condensation with citraconic acid. If it (V)

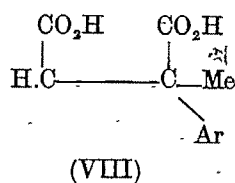
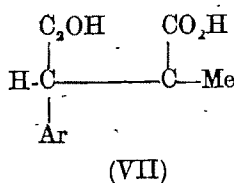
were the sole product of the reaction (5), it would have defeated the advantage of using the free acids for this investigation.

*p*-Nitrobenzene diazonium chloride reacts with mesaconic acid with less ease, but the acid formed is identical with the  $\alpha$ -methyl-*p*-nitrocinnamic acid (A), suggesting that the acids (IV) may be of the *trans* type.

Reactions are found to occur readily with those amines which are negatively substituted. Where the reaction is slow under the usual conditions, it can be quickened by a further increase of  $p_H$ . These facts show the importance of the diazo form ( $Ar-N_2-Cl$ ) which alone can provide free aryl radicals needed to carry the reaction on through a chain mechanism as suggested by Koelsch. Further support to the latter's view is obtained if the addition of hydrogen chloride to citraconic acid (Fittig, *Annalen* 1877, 188, 83) be compared with the reaction (5).



In the latter case the aryl addition<sup>1</sup> appears to be reverse to that of chlorine in (VI). The addition of hydrogen chloride to an olefine is always ionic (normal) and indicates how a so-called normal addition would occur (Mayo and Wallung, *Chem. Rev.*, 1940, 27, 355). Now in the light of the various cases of the peroxide directed addition of hydrogen bromide to olefines (Mayo and Wallung, *loc cit.*, p. 360) a chain mechanism is involved in those cases at least where an addition occurs reverse to the normal addition, as it happens with reaction (5). This conclusion in the present case enjoins that the radical (VII) should be more stable than (VIII).



According to the views of Koelsch this would mean that the lone electron in (VII) resonates with more facility, to acquire stability, within the adjoining unsaturated group than in (VIII). This seems to be justifiable because the +I (electron release) effect of the methyl group would facilitate the tendency for resonance of the lone electron in (VII) rather than in (VIII).

## E X P E R I M E N T A L

Citraconic acid was prepared according to the directions of Shriner, Ford and Roll ("Organic Synthesis", Collective vol. II, pp. 368,140). Mesaconic acid was



prepared by the isomerisation of citraconic acid by a trace of bromine in chloroform in sunlight (Fittig, *Annalen*, 1877, 188, 73). *p*-Bromobenzaldehyde was obtained by the oxidation of *p*-bromotoluene ("Organic Synthesis", Collective vol, II, p. 442).

*Condensation of p-Nitrobenzene diazonium Chloride with Citraconic Acid.*—*p*-Nitroaniline (6.9 g.) was dissolved in hydrochloric acid (12.5 c.c.), the hydrochloride, precipitated by ice-water (15 c. c.), was diazotised with sodium nitrite (3.5 g.) in water (10 c. c.). The filtered diazonium solution was added to citraconic acid (6.5 g.) in acetone (30 c. c.) containing sodium acetate (11.5 g.), copper chloride (2 g.) dissolved in water (15 c. c.). The mixture was stirred throughout the brisk reaction which lasted for  $\frac{1}{2}$  hour. A reddish brown solid separated which was filtered off, washed and then extracted with warm saturated sodium bicarbonate solution (10 c. c., thrice). The extract on acidification gave a yellowish white solid (1.5 g.). It was dried, and then triturated in the cold with benzene (5 c. c., thrice) to remove *p*-nitrophenol etc. The benzene-insoluble portion was crystallised from boiling alcohol in rhombic crystals (A), m. p. 208-209°. (Found: N, 6.8; equiv., 202.  $C_{10}H_7O_4N$  requires N, 6.76 per cent. Equiv., 207). It decolourised 1% potassium permanganate and bromine water immediately in the cold. The neutral residue failed to give these reactions of unsaturation. The acid (III) of m. p. 168' (cf. Wulfung, *Ber.*, 1907, 40, 1593; Koelsch *et al.*, *J. Amer. Chem. Soc.*, 1944, 66, 413) was absent in the mother-liquor left behind after crystallising out the acid (A).

In a separate experiment the gas evolved was first scrubbed through a wash bottle containing water (acidulated with hydrochloric acid to minimise solubility of  $CO_2$ ) to retain acetone vapours etc, and then through clear saturated baryta water, protected from the outside carbon dioxide. Considerable amount of barium carbonate was obtained. A blank experiment, without citraconic acid, gave only a little opalescence.

*Preparation of  $\alpha$ -Methyl-*p*-nitrocinnamic Acid.*—A mixture of *p*-nitrobenzaldehyde (1.1 g.), anhydrous sodium propionate (0.6 g.) and propionic anhydride (3 c. c.) was heated under reflux at 180° for 8 hours. The mass was slightly cooled and extracted with warm sodium carbonate solution. The extract on acidification gave a solid as rhombic plates from alcohol, m. p. 208° (mixed m. p. with the acid A in the previous experiment, 206-208°). This acid had been obtained by Biehringer (*J. Chem. Soc.*, 1900, 77, 1235) by the oxidation of  $\alpha$ -methyl-*p*-nitrocinnamic aldehyde.

*Condensation of p-Bromobenzene diazonium Chloride with Citraconic Acid.*—*p*-Bromoaniline (8.6 g.) dissolved in hydrochloric acid (12.5 c. c.) and ice-water (15 c.c.) was diazotised with sodium nitrite (3.5 g.) in water (10 c. c.). The diazotised solution was condensed with a mixture of citraconic acid (6.5 g.), acetone (30 c. c.), sodium acetate (11.5 g.), copper chloride (2 g.), water (15 c. c.) as before. The reaction was brisk and lasted for  $1\frac{1}{4}$  hours. The brownish semi-solid mass on extraction with warm aqueous sodium bicarbonate yielded an acid (1.2 g.) which on crystallisation from petroleum ether separated in colourless needles, m. p. 172-73°. (Found: Br, 32.98; equiv., 238.  $C_{10}H_6O_2Br$  requires Br, 33.1 per cent. Equiv., 241). It gave tests for unsaturation, whereas the neutral residue did not, showing the absence of stilbene. In a separate experiment the gas phase was found to contain carbon dioxide:

*Preparation of  $\alpha$ -Methyl-*p*-bromocinnamic Acid.*—*p*-Bromobenzaldehyde (1.4 g.), anhydrous sodium propionate (0.6 g.) and propionic anhydride (3 c. c.) were refluxed for 8 hours at 170°. The cooled mass was extracted with warm aqueous sodium carbonate. The extract on acidification yielded an acid which crystallised from ether as white needles, m. p. 172-73° (mixed m. p. with the acid in the previous experiment).

*Condensation of other Aryl Diazonium chlorides with Citraconic Acid.*—Condensations were effected using amine (0.5*M*) and the acid, and sodium acetate (11.5 g.) just as in the first experiment. The melting points and other relevant properties of the corresponding  $\alpha$ -methyl- $\beta$ -aryl-acrylic acids are recorded below as given in the literature for the sake of comparison.

$\alpha$ -Methyl- $\beta$ -aryl-acrylic acids						
Amine (diazotised) and wt.	Nature and time.	Crude mixture.	Properties of pure acids		Equivalent weight	
			Found.	As given in lit.	Found.	Calc.
<i>o</i> -Nitro-aniline (0.9 g.)	Very brisk; 1½ hrs	Brown, semi-solid	m. p. 198-99° (from petroleum ether) in prisms.	m. p*. 198° (from alcohol) in monoclinic prisms	203	C <sub>10</sub> H <sub>9</sub> O <sub>4</sub> N : 207
<i>m</i> -Nitro-aniline (6.9 g.)	Do; 1 hr.	Brown, solid	m. p. 196-97°; yellow fine crystals from alcohol	m. p.† 197.5° powder. Sol. in alcohol, ether benzene, less in ligroin.	204	C <sub>10</sub> H <sub>9</sub> O <sub>4</sub> N : 207
$\alpha$ -Naphthyl-amine (7.15 g.)	Slow; 1 hr.	Reddish brown, solid and tar	m. p. 150, needles from benzene.	m. p. ‡ 151°, needles from benzene	208	C <sub>14</sub> H <sub>13</sub> O <sub>2</sub> : 212
$\beta$ -Naphthyl-amine (7.15 g.)	Brisk; 1 hr.	Rose coloured	m. p. 117-22°	Nil	190	Slightly impure

\* Ranfaldi, *Rend. R. Accad. Scienze Fis. Mat. Napoli*, 1910, (3), 16, 0.226; *Z. Kr.*, 52, 314.

† Rohde, *Ber.*, 1890, 23, 1900.

‡ Rousset, *Bul. soc. chim.*, 1897 *iii*, 17, 813.

Nitrobenzene diazonium chlorides (*o*, *m* & *p*) could react even in the presence of 7 g. sodium acetate ( $p_H$  ca. 1-3). Higher amounts (22 g.) or the use of borax (14 g.) was found beneficial ( $p_H$  ca. 7-9) only in the case of naphthalene diazonium chlorides; in other cases this caused slackening in the evolution of the gas. The  $\beta$ -naphthalene salt reacted more readily than the  $\alpha$ -isomer. In every case considerable amounts of neutral tarry matter, consisting presumably of diphenyl derivatives, the parent hydrocarbon, and its halogen derivatives etc., were also present. Also under the above conditions, reactions could not be brought about with diazotised aniline, sulphanilic acid and anthranilic acid.

*Condensation of p-Nitrobenzene diazonium Chloride with Mesaconic Acid.*—Diazotised *p*-nitroaniline (6.9) was condensed with mesaconic acid (6.5 g.) in the presence of other

ingredients as in the first experiment. The reaction was not as brisk (3-2½ hours) as in the case of citraconic acid. A brown solid was obtained (1.2 g.) from which after extraction with sodium carbonate, acidification of the extract, trituration with benzene, a solid was obtained which crystallised out from boiling alcohol in prisms, m. p. 208° (mixed m. p. with the acid A).

Work is in progress to utilise condensations of the above type to synthesise cinnamic acid and arylpropionic acids.

DEPARTMENT OF ORGANIC AND PHARMACEUTICAL  
CHEMISTRY, PUNJAB UNIVERSITY INSTITUTE  
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*Received July 11, 1948.*

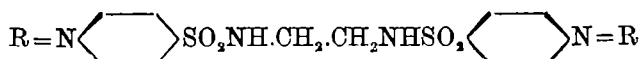
# STUDIES IN SULPHANILAMIDES. PART XII. SOME DIANILS AND DIACYLS OF ETHYLENE-BIS-N<sup>1</sup>-SULPHANILAMIDE AND SOME N<sup>4</sup>-SULPHANIL-AMIDO ALIPHATIC ESTERS\*

BY HABKRISHAN LAL BAMI, BALKRISHNA HARIHAR IYER AND  
PRAPHULLA CHANDRA GUHA

Ethylene-bis-N<sup>1</sup>-sulphanilamide has been reacted with aromatic aldehydes to give the dianils. Diacyls of ethylene-bis-N<sup>1</sup>-sulphanilamide have been prepared by reacting it with the acid chlorides of aliphatic monocarboxylic acids. Sulphanilamide has been condensed with some aliphatic bromo-esters to give the N<sup>4</sup>-sulphanilamido esters which are hydrolysed to give the free acids.

Considering the encouraging bactericidal activity of anils of sulphanilamide and sulpha-pyridine (Kolloff, and Hunter, *J. Amer. Chem. Soc.*, 1940, **62**, 158, 1647; Grey *et al.*, *Biochem. J.*, 1937, **31**, 724; Fournau *et al.*, *Compt. rend. soc. Biol.*, 1937, **208**, 299) dianils of ethylene-bis-N<sup>1</sup>-sulphanilamide (Bami, Iyer and Guha, *Science & Culture*, 1945, **11**, 269) of type A from (I) to (IX) have been prepared by heating the amine with 2 molecular proportions of different aldehydes at suitable temperatures without any solvent. The anils are light coloured powders insoluble in acid, alkali and usual organic solvents. They could not be crystallised and were purified by removing the starting materials. These compounds have sharp melting points and were obtained in good yields.

## TYPE A.

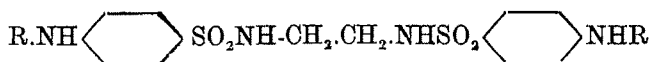


- |   |  |
|---|--|
| (I) R = C <sub>6</sub> H <sub>5</sub> .CH-                              | (VI) R = α-(OH)-C <sub>10</sub> H <sub>7</sub> .CH-          |
| (II) R = m-NO <sub>2</sub> .C <sub>6</sub> H <sub>4</sub> .CH-          | (VII) R = C <sub>6</sub> H <sub>5</sub> .CH <sub>2</sub> CH- |
| (III) R = o-(OH) C <sub>6</sub> H <sub>4</sub> .CH-                     | (VIII) R = C <sub>6</sub> H <sub>5</sub> .CH = CH.CH-        |
| (IV) R = p-(OCH <sub>3</sub> ) C <sub>6</sub> H <sub>4</sub> .CH-       | (IX) R = C <sub>4</sub> H <sub>9</sub> O-                    |
| (V) R = 3-(OH)-4 (OCH <sub>3</sub> ) C <sub>6</sub> H <sub>3</sub> .CH- |  |

Miller *et al.* (*J. Amer. Chem. Soc.*, 1939, **61**, 1198) have reported that activity of straight chain aliphatic acyl derivatives of sulphanilamide increases with increase in the number of carbon atoms in acyl residues from C<sub>2</sub> to C<sub>7</sub> after which there is a sharp drop in activity. Bergman and Haskellberg (*J. Chem. Soc.*, 1939, 1) suggested that increased fat solubility associated with lipophilic properties may be expected to be conferred on the resulting compound consequent to the introduction of fatty acid residues in the sulphanilamide molecule. With a view to conferring similar properties to ethylene-bis-N<sup>1</sup>-sulphanilamide (Bami *et al.*, *loc. cit.*) it has been reacted in pyridine solution with aliphatic acid chlorides having C<sub>2</sub> to C<sub>7</sub> carbon atoms, to form the corresponding diacyl derivatives of type B (I-VII). The products are usually insoluble in organic solvents and are purified by precipitation from their dilute alkali solutions with acid in the cold. White amorphous powders in good yields having sharp melting points are obtained.

\*A preliminary note of this work was published in *Science & Culture*, 1946, **12**, 152.

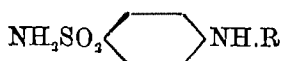
## TYPE B.



- |   |   |
|---|---|
| (I) $\text{R} = \text{CH}_3\text{CO}-$  | (V) $\text{R} = (\text{CH}_3)_2\text{CH} \cdot \text{CH}_2\text{CO}-$ |
| (II) $\text{R} = \text{CH}_3 \cdot \text{CH}_2 \cdot \text{CO}-$                    | (VI) $\text{R} = \text{CH}_3 \cdot (\text{CH}_2)_4 \cdot \text{CO}-$  |
| (III) $\text{R} = \text{CH}_3 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{CO}-$ | (VII) $\text{R} = \text{CH}_3 \cdot (\text{CH}_2)_5 \cdot \text{CO}-$ |
| (IV) $\text{R} = (\text{CH}_3)_2\text{CH} \cdot \text{CO}-$                         |   |

Streptosol (sulphanilylglycin), a soluble sulpha-drug has been reported to be therapeutically active (Kolloff, *J. Amer. Chem. Soc.*, 1938, **60**, 950; U. S. patent, 2142847). It was therefore considered worth while to prepare other similar N<sup>4</sup>-sulphanil-amido aliphatic esters and their corresponding free acid derivatives. N<sup>4</sup>-sulphanil-amido-acetic ester and acid (F. P. 816988; B. P. 470462; Trefouel *et al.*, *Ann. Inst. Pasteur*, 1937, **58**, 30) and N<sub>4</sub>-sulphanilamidopropionic acid (Northey, *Chem. Rev.*, 1940, **27**, 85) have already been reported in literature but no details are available. By reacting sulphanilamide with different aliphatic α-bromo esters in absolute alcohol compounds (I), (III), (V), (VII) and (IX) of type C have been obtained which on hydrolysis give (II), (IV), (VI), (VIII) and (X), respectively.

## TYPE C.



- |   |  |
|---|--|
| (I) $\text{R} = \text{CH}_2\text{COOC}_2\text{H}_5$                       | (VI) $\text{R} = \text{CH}_2\text{CH}_2\text{CH}_2\text{COOH}$           |
| (II) $\text{R} = \text{CH}_2\text{COOH}$                                  | (VII) $\text{R} = \text{CH}(\text{COOC}_2\text{H}_5)_2$                  |
| (III) $\text{R} = \text{CH}_2\text{CH}_2\text{COOC}_2\text{H}_5$          | (VIII) $\text{R} = \text{CH}(\text{COOH})_2$                             |
| (IV) $\text{R} = \text{CH}_2\text{CH}_2\text{COOH}$                       | (IX) $\text{R} = \text{CH}(\text{C}_6\text{H}_5)\text{COOC}_2\text{H}_5$ |
| (V) $\text{R} = \text{CH}_2\text{CH}_2\text{CH}_2\text{COOC}_2\text{H}_5$ | (X) $\text{R} = \text{CH}(\text{C}_6\text{H}_5)\text{COOH}$              |

## EXPERIMENTAL.

*Dianils of Ethylene-bis-N<sup>1</sup>-sulphanilamide (Type A).*

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-benzylidene-sulphanilamide) (I).*—Ethylene-bis-N<sup>1</sup>-sulphanilamide (1.8 g.) and freshly distilled benzaldehyde (1 g.) were mixed together and heated for 4 hours at 150° in an oil-bath. The reactants formed a homogeneous mass and water drops collected on the cooler portions of the vessel. The product was stirred with hot alcohol and filtered, washed with alcohol till free of all unreacted benzaldehyde and was ground with dilute hydrochloric acid (3 %, 15 c.c.). The acid-insoluble product was filtered, washed well with water and alcohol and finally dried as a white amorphous powder, m.p. 241-42°, yield 2.6g. (Found : N, 10.77.  $\text{C}_{28}\text{H}_{26}\text{O}_4\text{N}_4\text{S}_4$  requires N, 10.25 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-m-nitrobenzylidene-sulphanilamide) (II).*—Ethylene-bis-N<sup>1</sup>-sulphanilamide (1.8 g.) and m-nitrobenzaldehyde (1.5 g.) were powdered together and heated at 100-120° for 2½ hours. The mixture melted and solidified into a light yellow solid. The product was isolated and purified as described in (I) as a light yellow powder, m.p. 211-12°, yield 3.1 g. (Found: N, 12.91.  $\text{C}_{28}\text{H}_{24}\text{O}_6\text{N}_6\text{S}_4$  requires N, 13.23 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-o-hydroxybenzylidene-sulphanilamide) (III).*—Ethylene-bis-N<sup>1</sup>-sulphanilamide (1.8 g.) and salicylaldehyde (1.2 g.) were heated together for 2 hours at

135-145°. The product was worked up as in (I); m. p. 245°, yield 2.5 g. (Found: N, 9.42.  $C_{28}H_{26}O_6N_4S_2$  requires N, 9.68 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-p-methoxybenzylidene-sulphanilamide)* (IV).—Ethylene-bis-N<sup>1</sup>-sulphanilamide (1 g.) and anisaldehyde (0.7 g.) were heated together for 2½ hours at 140-150°. A pasty mass was obtained which did not improve by stirring with alcohol or ether. This was kept in contact with water for 2 days when it solidified. The product was isolated and purified as in (I) as a white amorphous powder, m.p. 168-69°, yield 1.3 g. (Found: N, 8.90.  $C_{30}H_{30}O_4N_6S_2$  requires N, 9.42 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-3-hydroxy-4-methoxybenzylidene-sulphanilamide)* (V).—Ethylene-bis-N<sup>1</sup>-sulphanilamide (1 g.) and vanillin (0.9 g.) were heated for 3 hours at 150°. The compound was isolated and purified from its crude pasty form as in (IV) as a light coloured powder, m.p. 237° (decomp.), yield 0.9 g. (Found: N, 8.25.  $C_{30}H_{34}O_8N_4S_2$  requires N, 8.77 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-α-hydroxynaphthylidene-sulphanilamide)* (VI).—Ethylene-bis-N<sup>1</sup>-sulphanilamide (1 g.) and α-hydroxynaphthaldehyde (1.4 g.) were heated together for 2 hours at 130-140°. The product was isolated as under (I) in the form of a brownish yellow powder, m.p. 275-77°, yield 2 g. (Found: N, 8.33.  $C_{36}H_{32}O_6N_4S_2$  requires N, 8.25 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-phenylacetylidene-sulphanilamide)* (VII).—Ethylene-bis-N<sup>1</sup>-sulphanilamide (1 g.) and phenylacetaldehyde (0.7 g.) were heated for 1½ hours at 150°. The product obtained as under (I) was a light yellow powder, m.p. 133°, yield 1.3 g. (Found: N, 9.1.  $C_{30}H_{30}O_4N_4S_2$  requires N, 9.75 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-cinnamylidene sulphanilamide)* (VIII).—Ethylene-bis-N<sup>1</sup>-sulphanilamide (2 g.) and freshly distilled cinnamic aldehyde (1.5 g.) were heated together for 1½ hours at 130°. The mixture was worked up as in (I) and the product obtained as a light brown powder, m.p. 172°, yield 2.8 g. (Found: N, 9.12.  $C_{32}H_{30}O_4N_4S_2$  requires N, 9.36 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-furfuralidene-sulphanilamide)* (IX).—Ethylene-bis-N<sup>1</sup>-sulphanilamide (1.5 g.) and furfuraldehyde (2 c.c.) were heated together for 2 hours at 150°. The product was isolated as in (I) as a light coloured powder, m.p. 225°, yield 1.3 g. (Found: N, 10.34.  $C_{24}H_{22}O_6N_4S_2$  requires N, 10.65 per cent).

#### *Diacyls of Ethylene-bis-N<sup>1</sup>-sulphanilamide (Type B).*

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-acetylsulphanilamide)* (I).—Ethylene-bis-N<sup>1</sup>-sulphanilamide (3.7 g.) was taken in dry pyridine (10 c.c.) and acetyl chloride (2 g.) was carefully added to it drop by drop. The mixture was heated on a water-bath for 1 hour under anhydrous conditions. The mixture was diluted with water (15 c.c.) and hydrochloric acid (2 c.c., 10%), when the product came out as a semi-solid mass. The product was dissolved in minimum alkali solution (2 %) and the alkali solution after stirring with charcoal was filtered and acidified in cold. The white precipitate was collected, washed well with water and alcohol and finally dried as a white amorphous powder, m. p. 275°, yield 4 g. (Found: N, 12.37.  $C_{18}H_{22}O_6N_4S_2$  requires N, 12.33 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-propionyl-sulphanilamide)* (II).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (3.7 g.) and propionyl chloride (2 g.) were reacted together in pyridine and the product obtained as in (I) as a white amorphous powder, m.p. 271°, yield, 3.8 g. (Found: N, 11.41.  $C_{20}H_{26}O_6N_4S_2$  requires N, 11.6 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-butyryl-sulphanilamide)* (III).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (3.6 g.) and butyryl chloride (2 g.) were reacted together and purified product obtained as in (I) as a white amorphous powder, m. p. 262-63°, yield 4 g. (Found: N, 10.52.  $C_{22}H_{30}O_6N_4S_2$  requires N, 10.98 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-isobutyryl-sulphanilamide)* (IV).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (3.6 g.) and isobutyryl chloride (2 g.) were reacted and the product isolated as in (I). as a white amorphous powder, m. p. 256°, yield 3 g. (Found: N, 10.29.  $C_{22}H_{30}O_6N_4S_2$  requires N, 10.98 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-isovaleryl-sulphanilamide)* (V).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (3.7 g.) was added to benzene (20 c. c.), and to this mixture isovaleryl chloride (2.4 g.) was added and the mixture refluxed for 6 hours on a water-bath under anhydrous conditions. The solid obtained was filtered and washed with ether and alcohol and finally obtained as a white amorphous powder after precipitating twice from its dilute alkali solution with acid in cold, and subsequent crystallisation from alcohol, m. p. 202°, yield 4.4 g. (Found: N, 10.0.  $C_{24}H_{31}O_6N_4S_2$  requires N, 10.4 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-caproyl-sulphanilamide)* (VI).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1.8 g.) and caproyl chloride (4 g.) were reacted together and the product obtained as in (V) as a light coloured amorphous powder, m. p. 206°, yield 1.2 g. (Found: N, 9.3.  $C_{26}H_{38}O_6N_4S_2$  requires N, 9.89 per cent).

*Ethylene-bis-N<sup>1</sup>-(N<sup>4</sup>-heptoyl-sulphanilamide)* (VII).—Ethylene-*bis*-N<sup>1</sup>-sulphanilamide (1.8 g.) and heptoyl chloride (1.5 g.) were reacted in pyridine and the product obtained as in (I) as a light coloured powder m. p. 182°, yield 1.5 g. (Found: N, 8.9.  $C_{28}H_{42}O_6N_4S_2$  requires N, 9.42 per cent).

#### *N<sup>4</sup>-Sulphanilamido-aliphatic Esters and Acids (Type C).*

*N<sup>4</sup>-Sulphanilamidoacetic Ester* (I).—Sulphanilamide (7 g.), absolute alcohol (20 c. c.) and ethyl bromoacetate (4 g.) were refluxed together on a water-bath for 12 hours. Sulphanilamide gradually went into solution and afterwards, alcohol was distilled off and the semi-solid mass was stirred with alcohol-free ether and filtered. Ether-insoluble product was washed with a little more ether, dried and ground with hydrochloric acid (5%, 20 c.c.). The acid-insoluble product was filtered, washed with water and crystallised from dilute alcohol after treating with charcoal (norit). The product was insoluble in other organic solvent and obtained as a white silky needles, m. p. 136-38°, yield 4.2 g. (Found: N, 10.7; S, 12.1.  $C_{10}H_{11}O_4N_2S$  requires N, 10.8; S, 12.4 per cent).

*N<sup>4</sup>-Sulphanilamidoacetic Acid* (II).—N<sup>4</sup>-Sulphanilamidoacetic ester (4 g.) and potassium hydroxide solution (10%, 15 c.c.) were refluxed together for 4 hours. The solution was filtered and acidified with minimum hydrochloric acid (15%). The precipitated product was filtered, washed with water (2 c. c.) and crystallised from hot water after treating with charcoal (norit) as a white amorphous powder, m. p. 245° (decomp.), yield 2.8 g. (Found: N, 12.21.  $C_8H_9O_4N_2S$  requires N, 12.1 per cent).

*N*<sup>1</sup>-Sulphanilamido- $\alpha$ -propionic Ester (III).—Sulphanilamide (7 g.) and  $\alpha$ -bromoethyl propionate (5 g.) were reacted together and a product obtained as in (I). It was crystallised from dilute alcohol as a white amorphous powder, m. p. 110°, yield 4 g. (Found: N, 10.51.  $C_{11}H_{16}O_4N_2S$  requires N, 10.3 per cent).

*N*<sup>1</sup>-Sulphanilamido- $\alpha$ -propionic Acid (IV).—*N*<sup>1</sup>-sulphanilamido- $\alpha$ -propionic ester (2.7 g.) and potassium hydroxide (1.5 g.) in water (20 c.c.) were refluxed together for 6 hours. The solution was concentrated to a smaller volume (nearly 7 c.c.) and worked up as under (II). The product was obtained as a white amorphous powder, m. p. 180-81°, yield 2 g. (Found: N, 11.12.  $C_9H_{12}O_4N_2S$  requires N, 11.47 per cent).

*N*<sup>4</sup>-Sulphanilamido- $\alpha$ -butyric Ester (V).—Sulphanilamide (10 g.) and ethyl  $\alpha$ -bromobutyrate (6 g.) in absolute alcohol (50 c.c.) were refluxed for 24 hours. The product was isolated and purified as under (I) as a white amorphous product, m. p. 117°, yield 4.5 g. (Found: N, 10.18; S, 11.6.  $C_{12}H_{18}O_4N_2S$  requires N, 9.79; S, 11.14 per cent).

*N*<sup>4</sup>-Sulphanilamido- $\alpha$ -butyric Acid (VI).—*N*<sup>4</sup>-Sulphanilamido- $\alpha$ -butyric ester (3 g.) was hydrolysed and the product obtained in exactly the same manner as in (II) as a white amorphous powder, m. p. 172°, yield 2.7 g. (Found: N, 10.8.  $C_{10}H_{14}O_4N_2S$  requires N, 10.25 per cent).

*N*<sup>4</sup>-Sulphanilamidodiethyl Malonate (VII).—Sulphanilamide (7 g.) and ethyl bromomalonate (5 g.) in absolute alcohol (20 c.c.) were refluxed together for 15 hours. The product was isolated and crystallised as described in (I) as a white crystalline powder, m. p. 171-72°, yield 4.5 g. (Found: N, 8.42.  $C_{13}H_{18}O_6N_2S$  requires N, 8.5 per cent).

*N*<sup>4</sup>-Sulphanilamidomalonic Acid (VIII).—*N*<sup>4</sup>-Sulphanilamidodiethyl malonate (2.3 g.) was hydrolysed as under (IV). The product was obtained as a white powder after crystallisation from water, m. p. 236° (decomp.), yield 2 g. (Found: N, 10.3.  $C_9H_{10}O_6N_2S$  requires N, 10.21 per cent).

*Sulphanilamidophenylacetic Ester* (IX).—Sulphanilamide (7 g.) ethyl bromophenylacetate (5 g.) in absolute alcohol (25 c.c.) were refluxed together for 15 hours. The alcohol was distilled off and the residue was stirred with benzene (15 c.c.). The product was filtered and washed with ether, and worked up as described in (I). Finally crystallised from dilute alcohol it was obtained as a white amorphous powder, m. p. 126°, yield 6 g. (Found: N, 8.56; S, 9.4.  $C_{16}H_{18}O_4N_2S$  requires N, 8.38; S, 9.58 per cent).

*N*<sup>4</sup>-Sulphanilamidophenylacetic Acid (X).—*N*<sup>4</sup>-Sulphanilamidophenylacetic ester (3.3 g.) was saponified as in (II). In this case, the product was crystallised from dilute alcohol as a white powder, m. p. 189° (decomp.), yield 2 g. (Found: N, 8.8.  $C_{14}H_{14}O_4N_2S$  requires N, 9.15 per cent).



## THE REACTIVITY OF DIETHYL 2:4-DINITROPHENYLMALONATE

BY S. H. ZAHEER AND G. S. SIDHU

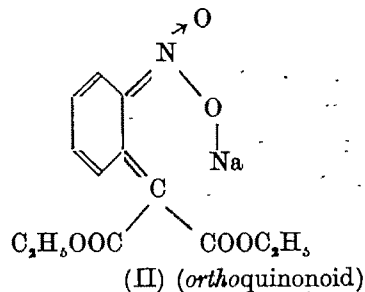
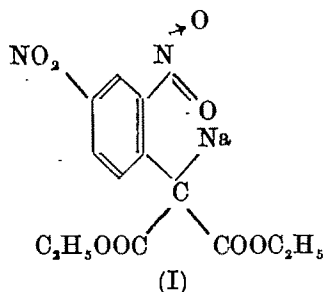
Diethyl 2:4-dinitrophenyl-*n*-propylmalonate has been prepared, an improved method for its preparation has been worked out and a tentative explanation for the remarkable stability and colour of its sodium derivative has been put forward.

It is well known that the halogen atom in 1-halogenated 2:4-dinitrobenzenes is reactive and yields condensation products with the sodium derivatives of acetoacetic and malonic esters. Considerable work has been done on this subject (Richter, *Ber.*, 1888, 21, 2470; Reissert and Heller, *Ber.*, 1904, 37, 4364; Borsche, *Ber.*, 1909, 42, 601; Dey and Doraiswami, *J. Indian Chem. Soc.*, 1933, 10, 309). None of the above workers, except Borsche, described any attempt to prepare substitution derivatives of 2:4-dinitrophenyl-acetoacetic and -malonic esters. Both these compounds readily yield their sodium derivatives but according to Borsche the sodium derivative of 2:4-dinitrophenylacetoacetic ester fails to react either with ethyl iodide or benzyl chloride, reacting, however, with a second molecule of bromo-2:4-dinitrobenzene to yield 2:4:2':4' tetranitrodiphenylacetoacetic ester (Borsche, *Ber.*, 1909, 42, 1311). He also failed to effect this condensation starting from  $\alpha$ -alkyl acetoacetic esters and allowing their sodium derivatives to react with 1-bromo-2:4-dinitrobenzene. Borsche concluded therefore that the hydrogen atom in the acetoacetic ester grouping of 2:4-dinitrophenylacetoacetic ester did not react with alkyl halides.

As there is no mention in literature of any attempt, either by the above mentioned or other authors, to condense the sodium derivative of diethyl 2:4-dinitrophenylmalonate with any alkyl halide and as the present authors required such compounds as intermediates in connection with other work, they tried the condensation of the above mentioned compound with propyl bromide as a test case. The condensation has been successfully effected both ways, that is, both by condensing sodio-propyl malonic ester with 1-chloro-2:4-dinitrobenzene and by condensing the sodium derivative of diethyl 2:4-dinitrophenylmalonate with propyl bromide, the solvents used being dry ether-benzene mixture in the first case (yield 54% of theory) and absolute ethyl alcohol in the second (yield 23% of theory). The yields obtained in the second stage of condensation are thus considerably less than those obtained in the first stage of condensation of the monosodio malonic ester with 1-chloro-2:4-dinitrobenzene (yield 90% of theory). It is thus obvious that the presence of 2:4-dinitrophenyl-group in the 2:4 dinitrophenylmalonic and -acetoacetic esters leads to the formation at the second stage of substitution, of stable sodium derivatives which undergo further condensation with alkyl halides only with reluctance in the case of malonic ester derivatives and not at all in the case of acetoacetic ester derivatives as found earlier by Borsche (*loc. cit.*).

The sodium derivative of diethyl 2,4-dinitrophenylmalonate is characterised by remarkable stability. It is a crimson-red, beautifully crystalline solid which is quite unlike other gelatinous sodio derivatives and decomposes only on heating above

120°. The stability and the colour of this compound might be explained as probably due to resonance, the structures mainly contributing to the mesomeric form possibly being (I) and (II).



The increased stability of this sodium compound would also explain its reduced reactivity and the consequent low yields obtained in its condensation with propyl bromide.

The present authors have also worked out a greatly improved method of preparing diethyl 2:4-dinitrophenylmalonate in 90% yield. This ester was first prepared by Richter (*loc. cit.*) by refluxing an equimolecular mixture of 1-bromo-2:4-dinitrobenzene and malonic ester with sodium ethoxide in absolute alcohol. The product obtained was reported to be an oil which Richter could crystallise only with great difficulty and by a tedious process. Dey and Doraiswami (*loc. cit.*) also claim to have prepared it subsequently by the same method. It is found by the present authors that the best results could be obtained by bringing about the condensation in dry ether using twice the molecular quantities of sodium and malonic ester. The sodium compound separated out as a crimson-red, crystalline solid on rubbing up the pasty reaction mass with a little ice-cold water. It was then decomposed by cold dilute nitric acid to give diethyl 2:4-dinitrophenylmalonate.

Attempts to hydrolyse diethyl 2:4-dinitrophenyl-*n*-propylmalonate have not yet succeeded. Among the hydrolytic agents tried by the present authors are aqueous and alcoholic sodium hydroxide, dilute hydrochloric acid, dilute sulphuric acid, concentrated hydrochloric acid and a mixture of glacial acetic and concentrated sulphuric acids. This obviously seems to be a case of steric hindrance in keeping with the observation of Hjelt (*Ber.*, 1896, 29, 110, 1864) that disubstituted malonic esters are hydrolysed only with great difficulty where the substituents are large in size.

## E X P R I M E N T A L

**Diethyl 2:4-Dinitrophenylmalonate.**—In a three-necked round bottom flask, fitted with an efficient mercury-sealed mechanical stirrer, a reflux condenser and a dropping funnel, the mono-sodium derivative of diethyl malonate was prepared from 2.3 g. of sodium, 30 c.c. dry ether, and 16g. of malonic ester. The flask was immersed in ice-cold water and a solution of 10.2 g. (0.05 mol.) of 1-chloro-2:4-dinitrobenzene in 100 c.c. of absolute ether was

added gradually and with constant stirring during the course of 2 hours. The ice-water was then removed and the contents refluxed for 9 hours. The ether was then decanted after cooling, the excess of malonic ester and any unreacted 1-chloro-2:4 dinitrobenzene coming over with the ether. Ice-cold water (60 c.c.) was then added to the brown pasty reaction mass left in the flask. A bright red crystalline precipitate (sodio-derivative of diethyl 2:4-dinitrophenylmalonate) was thus obtained and was filtered at the pump. The ethereal portion was extracted repeatedly with cold 3% sodium hydroxide till no more colour came in the alkali extract. The crystalline red precipitate was suspended in the alkali extract in a beaker and curhshed ice was added to it. Dilute nitric acid was then added drop by drop till the red colour was completely dischargrd. 2:4-Dinitrophenylmalonic ester separated as a pale yellow crystalline precipitate which gave colourless plates on recrystallisation from dilute alchool, m.p.  $51^{\circ}$ , yield 14.5 g. (90%). (Found: N, 8.32.  $C_{14}H_{14}O_8N_2$  requires N, 8.59 per cent).

The red sodio-derivative obtained above is remarkably stable towards air and water. It decomposes between  $120^{\circ}$  and  $125^{\circ}$  on heating in a capillary. (Found: N, 7.71.  $C_{13}H_{13}O_8N_2Na$  requires N, 8.05 per cent).

*Diethyl 2:4-Dinitrophenyl-n-propylmalonate*.—Diethyl propylmalonate (5 g., 0.025 mole), prepared as usual, was added drop by drop to 0.58 g. (0.025 mole) of sodium ribbon suspended in a mixture of 20 c.c. dry ether and 20 c.c. dry benzene cooled in water. After the addition was complete the mixture was refluxed for 10 minutes and the flask was then cooled in ice-water. 2:4-Dinitrochlorobenzene (0.025 mole, 5 g.) dissolved in 50 c.c. of absolute ether was then slowly added during the course of 2 hours. The mixture was finally refluxed for 7 hours and the ether and benzene then distilled off. The residue was treated with 1% cold hydrochloric and the acid decanted off from the oil which had separated. After washing the oil free of acid with water it was dissolved in 100 c.c. of cold alcohol and left over for slow evaporation. After about 3 weeks the mass became crystalline. On recrystallisation from dilute alcohol it gave colourless needles, m. p.  $72^{\circ}$ , yield 5 g. (54% of theory). (Found: N, 7.99.  $C_{16}H_{20}O_8N_2$  requires N, 7.61 per cent).

*Diethyl 2:4-Dinitrophenyl-n-propylmalonate from Propyl Bromide and Diethyl Sodio-2:4-dinitrophenylmalonate*.—The sodium derivative of 2:4-dinitrophenylmalonic ester (3.5g., previously washed with ether and dried in vacuum) was dissolved in 10 c.c. of absolute alcohol and refluxed for 10 hours with freshly distilled propyl bromide (1.3 g.). The alcohol was then distilled off and the residue acidified with cold 1% hydrochloric acid, the rest of the treatment being as above, m.p.  $73^{\circ}$  (mixed melting point with a specimen of this ester prepared by the first method), yield 0.85 g. (20% of theory). (Found: N, 7.99.  $C_{16}H_{20}O_8N_2$  requires N, 7.61 per cent.).

## KINETICS OF THE FORMATION OF ANILIDES. PART I.

N. T. VARTAK, N. L. PHALNIKAR AND B. V. BHIDE

The reaction between methyl esters of substituted benzoic acids and aniline has been studied with nitrobenzene and xylene as solvents. The reaction has been shown to be bimolecular and the activation energy,  $E$  and the probability factor,  $P$  have been calculated in each case. A mechanism, parallel to alkaline hydrolysis of esters, has been proposed and the effect of the substituents has been explained on the basis of this mechanism. A relationship is shown between the reaction velocity and the dipole moments of substituted benzoic acids.

The reaction of esters with aniline or other primary amines does not appear to have been studied in detail so far. Menshutkin (*Chem. Zentr.*, 1906, I, 551) studied the kinetics of the reaction of aliphatic acids with the excess of aniline, toluidines or xylydines. The reaction was confined to aliphatic acids. The reaction is catalysed by halogen acids or their ammonium salts.

Goldschmidt (*Ber.*, 1906, 39, 97) studied the velocity of reaction between aliphatic acids, aniline and toluidine and showed the reaction to be bimolecular. In the presence of picric acid as a catalyst, the reaction was of the first order and the temperature coefficient was about 2 as in the case of the catalysed reactions.

Davies (*Z. physikal. Chem.*, 1911, 78, 353) studied the rate of hydrolysis of anilides by sodium hydroxide with a view to ascertaining the effect of substituents on the rate of the reaction and these observed rates were compared with the equilibrium constant of the formation of anilides from the acid and an aromatic base. A parallelism between the two was shown. McBain and Davies (*Z. physikal. Chem.*, 1911, 78, 369) have compared the equilibrium constants of the anilides with the dissociation constants of acids and amines. There is also a parallelism between these constants and the effect of the substituents on them.

Audrieth and co-workers (*J. Amer. Chem. Soc.*, 1938, 60, 579; 1939, 61, 2387; 1940, 63, 2965) studied the reaction between esters and aliphatic amines in order to ascertain the mechanism of the reaction. They have suggested that the 'onium' ion is the active catalyst.

Betts and Hammett (*J. Amer. Chem. Soc.*, 1937, 59, 1568) studied the rates of reaction of phenylacetic esters with ammonia in methyl alcohol at 25° and showed that the two reactions occurred simultaneously, one uncatalysed reaction of ester with ammonia and a parallel base-catalysed reaction of ester with the amide ion.

The present communication deals with the kinetics of the reaction between aniline and methyl esters of twenty substituted benzoic acids.

## E X P E R I M E N T A L

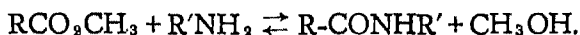
Aniline was dried over solid potassium hydroxide and fractionally distilled. Nitrobenzene was shaken with calcium carbonate and dried over calcium chloride. It was then distilled under reduced pressure. Xylene was dried over sodium and then over phosphorus pentoxide and distilled. All the esters were prepared by standard methods and purified after drying by fractional distillation. Top and bottom fractions were rejected and fractions boiling within less than one degree used for the experiments. The boiling points and other constants agreed closely with those reported in the literature. The solvents used were nitrobenzene and xylene.

The velocity constants were determined at four or more temperatures between 80° and 145° in a thermostat. The temperatures used were very much lower than the boiling points of the esters. The reaction was carried out in hard glass test-tubes in which a known volume of the reaction mixture of the requisite concentration was introduced.

*Method of Analysis.*—The test-tubes were removed from the thermostat, chilled and analysed according to the following procedure: (a) At the end of a certain period, a test-tube containing a reaction mixture of the base, the ester and the anilide in the solvent was taken out and chilled. (b) The well cooled mixture was then washed with a total quantity of 50 c. c. of 4% hydrochloric acid in four equal lots and the base was thus extracted from the reaction mixture in the washings. (c) The washings were collected and made up to a fixed volume (100 c. c.). A known volume of the washings was then analysed by the bromate-bromide method and the base estimated.

The method of analysis described above was checked by preparing synthetic mixture of the reaction products of similar concentration in nitrobenzene, xylene and chlorobenzene. The estimated quantity of the base agreed within 1% with the quantity actually taken.

*Nature of the Reaction.*—The reaction of a base and an ester can be represented as



The experiments were conducted to determine whether there was an equilibrium attained in the course of the reaction. When a reaction mixture containing methyl benzoate and aniline (both 0.1 g. mol./litre) in nitrobenzene was heated at 100° for 170 hours, the anilide formation occurred to the extent of about 97%. The reverse reaction was studied by heating at 100° for several hours a mixture of the anilide and methyl alcohol of the same concentration and in the same solvent in a closed system. The analysis of the mixture after 170 hours showed that the reverse reaction did not occur at all. It is concluded therefore that the reaction goes to completion and the reverse reaction is not appreciable.

The reaction has been shown to be bimolecular by carrying out experiments with different initial concentrations of the reactants in equimolecular proportions. The time required for 25% change varied inversely to the initial concentration within experimental errors as required for a reaction of the second order. Velocity constants were calculated by the usual equation for a reaction of the second order,

$$k = \frac{x}{ta(a-x)}$$

where  $k$  = the velocity constant ;  $a$  = initial concentration of each reactant ;  $x$  = change in concentration ;  $t$  = time.

The concentrations are all expressed in g. mols./litre and the time in hours. The following table gives the results of a typical experiment.

TABLE I

*Reaction between methyl benzoate and aniline at 100° in nitrobenzene.*

Aniline = 0.1 g. mol /litre ; methyl benzoate = 0.1 g. mol./litre.

Time.	$x$	$a-x$	$10k$ .	Time.	$x$	$a-x$ .	$10k$ .
0 hr.	0.00000	0.09300		5 hr	0.02790	0.06510	7.010
1	0.00620	0.08680	7.010	8	0.03472	0.05828	7.440
2	0.01240	0.08060	7.698	10	0.03840	0.06460	7.050
3	0.01474	0.07826	7.816	20	0.05398	0.03902	7.010
4	0.02146	0.07154	7.050	30	0.06225	0.03075	7.012
						Mean	7.22

The unsubstituted ester was found to behave abnormally and hence the velocity constants of the reaction between methyl benzoate and aniline were redetermined several times using different samples of aniline. The same value for velocity constants was obtained in each case.

The velocity constants were used to calculate the activation energy  $E$  and the probability factor,  $P$  by using the equation,

$$k = PZe^{-E/RT}$$

The values of  $E$ , thus obtained graphically, were checked by the method of least squares (cf. Hartmann, *J. Amer. Chem. Soc.*, 1944, 66, 1714). The probability factor  $P$  was determined in the same way.  $Z$  was assumed to be  $2.8 \times 10^{11}$  (cf. Hinshelwood, *J. Chem. Soc.*, 1936, 1357).

The following table gives the values of the velocity constants  $10k$ , the activation energies and the probability factors. The activation energies are given to the nearest 100 calories. The values actually obtained by calculation are given in brackets. In Fig. 1.  $\log k$  has been plotted against  $1/T$  for the reaction between aniline and methyl benzoate as a typical case.

Fig. 1.

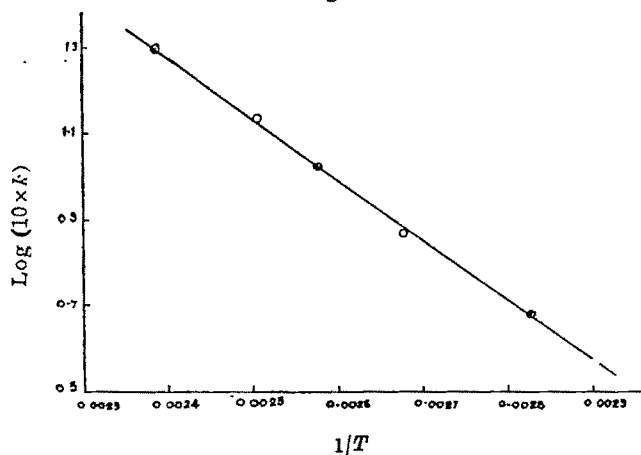


TABLE II

*Reaction between esters of substituted benzoic acids and aniline  
in nitrobenzene as solvent*

Temp.	10k.	E.	$P \times 10^4$ .	10k.	E.	$P \times 10^4$ .
	(1) Methyl benzoate.			(2) Methyl o-nitrobenzoate.		
80°	4.90			13.46		
100	7.22			18.21		
115	10.90			22.92	4200	
125	13.99	6200		26.33	(4210)	7.8
145	19.96	(6180)	7.3			
	(3) Methyl m-nitrobenzoate.			(4) Methyl p-nitrobenzoate.		
80°	16.25			18.52		
100	22.34			26.91		
115	28.16	3800		33.14	3800	
125	32.39	(3780)	15.5	37.16	(3770)	8.1
	(5) Methyl o-bromobenzoate.			(6) Methyl m-bromobenzoate.		
80°	11.58			13.81		
100	17.23			18.03		
125	27.52	4800		27.71	4500	
145	34.25	(4560)	8.7	38.65	(4540)	8.9
	(7) Methyl p-bromobenzoate.			(8) Methyl o-chlorobenzoate.		
80°	16.07			10.72		
100	22.26			14.79		
125	32.78	4300		21.88	4500	
145	39.41	(4280)	9.0	28.84	(4510)	5.2
	(9) Methyl m-chlorobenzoate.			(10) Methyl p-chlorobenzoate.		
80°	11.75			15.85		
100	16.60			21.88		
125	25.70	4500		30.20	4200	
145	35.83	(4480)	8.6	36.31	(4170)	8.8

TABLE II (contd.)

Temp.	10k.	E.	$P \times 10^7$	10k	E.	$p \times 10^7$
	(11) Methyl <i>o</i> -methoxybenzoate.			(12) Methyl <i>m</i> -methoxybenzoate		
100°	11.27			13.93		
115	14.79			17.71		
125	18.79	5000		20.34	4800	
145	25.73	(4980)	8.1	27.43	(4830)	3.2
	(13) Methyl <i>p</i> -methoxybenzoate.			(14) Methyl <i>o</i> -hydroxybenzoate.		
100°	15.26			11.23		
115	17.93			14.46		
125	24.53	4300		17.39	5400	1.0
145	32.13	(4270)	5.9	23.95	(5370)	
	(15) Methyl <i>m</i> -hydroxybenzoate.			(16) Methyl <i>p</i> -hydroxybenzoate.		
100°	12.24			14.42		
115	16.27			18.21		
125	20.93	5000		22.36	5000	
145	29.57	(4990)	1.9	29.50	(4960)	1.6
	(17) Methyl <i>o</i> -toluate,			(18) Methyl <i>m</i> -toluate.		
80°	5.23			7.51		
100	7.94			11.18		
115	12.51	4800		14.12	4700	
125	14.10	(4840)	5.2	16.63	(4720)	5.2
	(19) Methyl <i>p</i> -toluate.					
80°	8.63					
100	11.80					
115	15.16	4600				
125	17.40	(4630)	4.9			

Probability Factor, 'P'.—Table III gives the values of  $P$  and  $E$  of the reactions between methyl esters of substituted benzoic acid and aniline in nitrobenzene.

TABLE III

Substituent.	<i>Ortho.</i>		<i>Meta.</i>		<i>Para.</i>	
	$P \times 10^7$ .	E.	$P \times 10^7$ .	E.	$P \times 10^7$ .	E.
Nitro	7.8	4200	15.5	3800	8.1	3800
Bromo	8.7	4600	4.0	4800	9.0	4300
Chloro	5.2	4500	3.6	4500	8.8	4200
Methoxy	8.1	5000	3.2	4800	5.9	4300
Hydroxy	1.0	5400	1.9	5000	1.6	5000
Methyl	5.2	4800	5.2	4700	4.9	4600
Methyl benzoate	7.3	6200	—	—	—	—

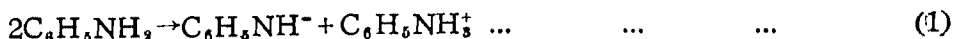
It will be observed from the above table, that the probability factor,  $P$  is of the order of  $10^{-7}$  and does not vary much, the maximum variation being 1:2.5 except in case of methyl *m*-nitrobenzoate and hydroxybenzoates. This variation might be more apparent than real, because the accuracy with



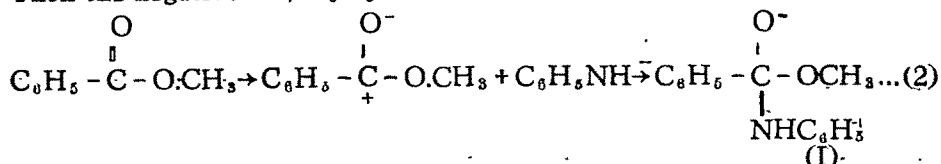


The mechanism of hydrolysis of esters is now known with considerable amount of certainty. On the other hand, perusal of literature shows that the reaction between aromatic bases and esters has not been studied in detail. Considerable amount of work on the reaction of ammonia and esters has been carried out by Audrieth and his co-workers (*loc. cit.*). More recently the same authors (*J. Amer. Chem. Soc.*, 1941, 63, 2965) have extended their investigation on the reactions of esters with primary aliphatic amines. Even with these data it is not possible to have any definite idea as regards the mechanism of the reaction. The only point that they make out is that in butylamine the reaction is acid-catalysed and probably "onium" salts act as catalysts.

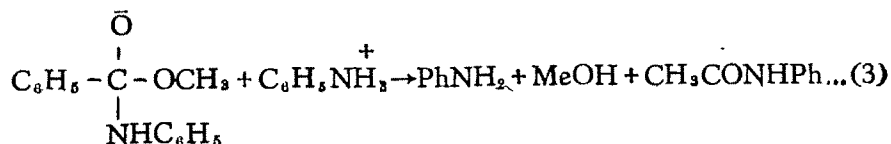
On the other hand Betts and Hammett (*J. Amer. Chem. Soc.*, 1937, 59, 1568) have shown that in alcoholic ammonia two reactions occur simultaneously, one of them being base-catalysed. It is not safe to assume that the mechanism in the present experiments is the same as advocated by Betts and Hammett (*loc. cit.*) as those authors have studied the reaction of ammonia in alcohol which is a protic solvent, while in the present case nitrobenzene, an aprotic solvent, has been used. However, tentatively the following scheme may be used to represent the mechanism of the reaction: The base first ionises according to



Then the negative ion,  $\text{C}_6\text{H}_5\text{NH}^-$  adds on to the molecule of the ester:



(I) is the complex formed by the addition of the negative ion. Then a molecule of alcohol is split off generating the anilide.

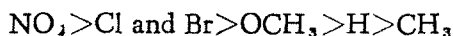


It will be observed from Table III that the effect of the substituent on the velocity of the reaction between ester and base is of the following order in all the three, *ortho*, *meta* and *para* series of substituents:



In the case of alkaline hydrolysis of esters (Tommila and Hinshelwood,

*J. Chem. Soc.*, 1938, 1801; Tommila, *Ann. Acad. Sci. Fennicae Ser.*, 1941, A, 57. No. 13, 3) the order in all the three series of substituents is



The order of the effect of substituents is identical in the present work as well as in the alkaline hydrolysis of esters up to  $\text{OCH}_3$  group. However, the effect of methyl group in the alkaline hydrolysis of esters is to retard the reaction, while in our case the velocity is increased. This anomaly of the position of the unsubstituted ester in the two series of reactions cannot be explained at this stage.

The effect of individual substituent in different positions follows the order:  $p > m > o$  in our case, while in alkaline hydrolysis of esters, the order, with the exception of  $\text{NO}_2$  group, is  $m > p > o$ . Thus the order of effect due to the position of the substituent is different in alkaline hydrolysis of esters from the effect of substituents in the present work. The values of constants for alkaline hydrolysis of esters for  $\text{OCH}_3$  group in *ortho* and *para* positions and that of  $\text{OH}$  in *o*-, *m*-, and *p*- positions are not known.

Likewise, the effect of substituents in benzoyl chloride in the benzylation of anilines (Hinshelwood and Williams, *J. Chem. Soc.*, 1934, 1079) follows the same order as in the alkaline hydrolysis of esters, and the reaction studied here, e.g.  $\text{NO}_2 > \text{Cl} > \text{H} > \text{CH}_3$ .

The results now may be discussed in the light of polarity of substituents. The mechanism proposed for the reaction shows that it is a class 'B' reaction. In class B reactions the activation energy,  $E$  is decreased and the reaction velocity increased by the presence of an electron attracting substituent, ( $\text{NO}_2$ ,  $\text{Cl}$ ,  $\text{Br}$ ,  $\text{OCH}_3$  etc.), while the presence of an electron repelling substituent ( $\text{CH}_3$ ) should decrease the reaction velocity. The effect of electron attracting groups is of the right order in the present reaction; the effect of the electron repelling group (to retard the reaction) is, however, not observed in the present case as noted above and is abnormal.

Velocity constants of esterification of benzoic acids with cyclohexanol have been determined by Hartman and co-workers (*J. Amer. Chem. Soc.*, 1944, 66, 1714). The results show that with the exception of *m*-toluic and *p*-methoxybenzoic acids the introduction of any substituent in the *m*- and *p*- positions in the benzoic acid molecule decreases the activation energy,  $E$  and  $P$  as well. In the case of *m*-toluic acid, the velocity constant is greater than benzoic acid, while in *p*-toluic acid it is slightly lower. Excluding *o*-substituents and *m*-methoxy and *m*-toluic acid, it is found that all the substituents increase the reaction velocity as compared with the unsubstituted benzoic acid, irrespective of the polarity of the substituents. This is quite analogous to the present case, where the methyl substituted benzoic esters have enhanced the rates. This similarity might be due to the second reactant being a cyclic derivative (cyclohexanol in their case and aniline in the present case).

Previous workers (*cf.* Evans, Morgan and Watson, *J. Chem. Soc.*, 1935, 1174) have observed that a relationship between velocity constants and dipole moments of the corresponding substituted benzenes is given by the relation,

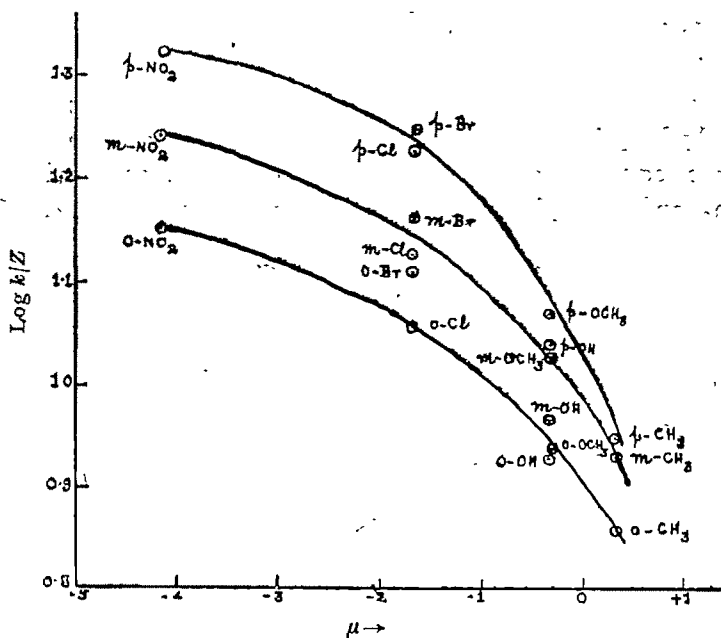
$$\log k/Z = \log k_0/Z_0 \pm x(\mu + \alpha\mu^2)$$

where  $Z = N^2 \sigma ab^3 (8\pi RT/M)^{1/2} \sigma ab$  being the mean diameter and  $\frac{1}{M} = \frac{1}{m_a} + \frac{1}{m_b}$ ,  $m_a$  and  $m_b$  being the respective molecular weights.

For comparative purposes  $\log k/Z$  may be taken as  $\log (k\sqrt{M})$ , as  $N^2 \sigma ab^3 (8\pi RT)^{1/2}$  will be nearly constant. (*cf.* Hinshelwood and Williams, *loc. cit.*)

In an isotypical series of reaction  $\log k_0/Z_0$  is constant and therefore if  $\log k/Z$  is plotted against dipole moment of substituted benzenes, a curve should be obtained. In the present work  $\log k/Z$  has been plotted against  $\mu$  (Fig. 3). Table IV gives the moments of substituted benzenes.

Fig. 3.



The moments of OCH<sub>3</sub> and OH groups are taken as  $\mu \cos 105^\circ$  (*cf.* Evans, Morgan and Watson, *loc. cit.*) since the moments of NO<sub>2</sub>, Cl, Br, CH<sub>3</sub> act in the plane of the benzene ring, while the moments of OCH<sub>3</sub> and OH are inclined to it.

Fig. 3 consists of three sets of curves representing three different series of substituents, o, m and p. The p- and m-hydroxy substituents

do not fall on the curve due to the low  $P$  factors. The unsubstituted ester, however, gives too low a value for the velocity constant and has therefore been excluded. In the present case  $\log k_0/Z_0$  does not represent the velocity constant for the unsubstituted ester.

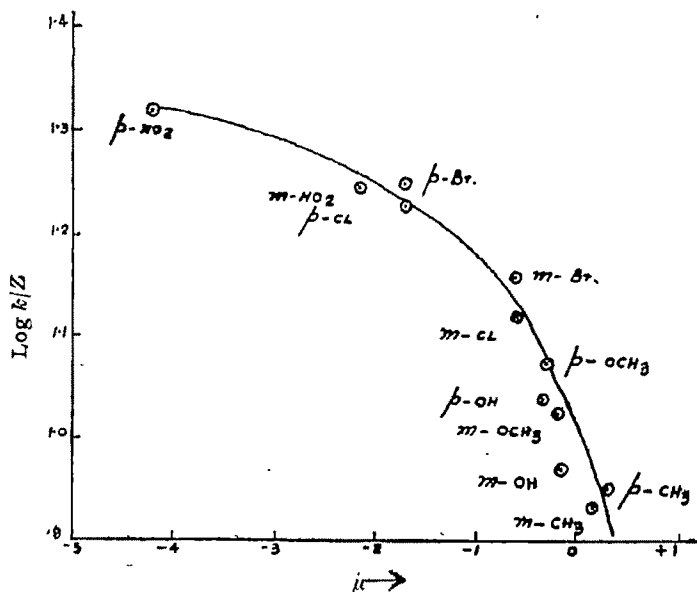
TABLE IV

Substituent	Dipole moment	Effective moment.	Effective moment (meta)	Substituent.	Dipole moment.	Effective moment.	Effective moment. (meta)
1. NO <sub>2</sub>	-4.24		-2.12	6. CH <sub>3</sub>	0.37		0.18
2. Cl	-1.73		-0.86	7. F	-1.27		-0.78
3. Br	-1.71		-0.85	8. I	-1.35		-0.65
4. CH	-1.40	-0.35	-0.17	9. OC <sub>2</sub> H <sub>5</sub>	-1.40	-0.36	-0.18
5. OCH <sub>3</sub>	-1.35	-0.84	-0.17	10. NH <sub>2</sub>	1.48	0.39	0.195

Dipole moments of 1–5 and 7–10 taken from Groves and Sugden (*J. Chem., Soc.*, 1935, 971; 1937, 1782) and that of No. 6 from Groves and Baker (*ibid.*, 1939, 1147).

This observation is quite different from the conclusions drawn by Evans, Morgan and Watson (*loc. cit.*). These workers exclude *o*-substituted compounds and also all resonating groups including the halogens and then proceed to show that the relationship holds irrespective of whether the substituent is in the *p*- or *m*- position. When their observations are studied in detail for the two reactions: (a) acid catalysed prototropy of nuclear substituted acetophenones and (b) alkaline hydrolysis of esters, the agreement between the values of  $E$  calculated from the equation and those actually observed, rests with respect to nitro, halogens and methyl groups only in the meta position *i. e.* only four cases.

Fig. 4.



Moreover, while drawing the curves Waston and co-workers have not taken into consideration the effective moments of the *meta*-substituted compounds which will have an effective moment of  $\mu \cos 60^\circ$  on the carbonyl carbon atom which is the centre of reaction. The angle  $60^\circ$  is only approximate as this is likely to be changed by the presence of different substituents. If  $\log (k\sqrt{M})$  is plotted against the effective moments of substituted benzenes our results show that a smooth curve results representing all the *m*- and *p*-substituted compounds (Fig. 4). Even *m*- and *p*-hydroxy compounds show little divergence from the curve. In the case of *ortho*-substituted compounds steric hindrance is operative and hence *ortho*-substituted esters are not taken into consideration. A similar relationship is not observed between  $E$ , the activation energy, and  $\mu$  owing to variations in the probability factor,  $P$ .

The above discussion can be rendered more definite if the dipole moments of esters of substituted benzoic acids are known. Work in this direction is in progress.

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# STUDIES IN GLASS SYSTEMS. REFRACTOMETRIC MEASUREMENTS OF ALKALI SULPHATES DISSOLVED IN FUSED BORAX GLASS

BY SUBODH KUMAR MAJUMDAR AND SASADHAR DIGAR

The values of the mole refraction ( $R$ ) of solutions of highly purified samples of  $\text{Li}_2\text{SO}_4$ ,  $\text{Na}_2\text{SO}_4$  and  $\text{K}_2\text{SO}_4$  in fused glass in different concentrations have been compared to those of the pure crystal and of the aqueous solution at infinite dilution. The values exhibit considerable departure, attributable to the strong deformation which these salts suffer in solid solution in glass medium. The slope of the  $R$ - $c$  curve is positive in every case (cf. the works of Fajans' school) implying meagre dissociation of the salt in the glass medium. The densities of the samples exhibit some peculiarities which can be explained by the recent views about the structure of glasses as proposed by Warren and Zachariasen.

The present work is an extension of the work done by one of us (S. K. M.) on the study of deformation of polar crystals dissolved in glass (Wulff and Majumdar, *Z. physikal. Chem.*, 1936, B, 31, 319; Majumdar and Sarma, *J. Indian Chem. Soc.*, 1942, 19, 241; Majumdar and Saha, *ibid.*, 1945, 22, 147; Majumdar and Banerjee, *ibid.*, 1946, 23, 149). The object of the work is to study the deformability of alkali sulphates ( $\text{Li}_2\text{SO}_4$ ,  $\text{Na}_2\text{SO}_4$  and  $\text{K}_2\text{SO}_4$ ) dissolved in fused borax glass as shown by the mole-refraction values.

## EXPERIMENTAL

*Preparation of the Samples.*—Lithium sulphate was prepared by dissolving pure lithium carbonate in just sufficient sulphuric acid, boiling off the dissolved carbon dioxide and crystallising in a vacuum desiccator over sulphuric acid. The salt was purified by twice recrystallising in a similar way. Merck's "guaranteed reagent" variety of the other salts were dissolved in conductivity water and twice recrystallised.

The samples were heated in a hot air-oven until constant weights were obtained. The samples of the glasses were obtained in the manner described in a previous communication (Majumdar and Banerjee, *loc. cit.*).

*Analysis of the Samples.*—A weighed amount of the glass was dissolved in hot water and treated with a slight excess of barium chloride solution in presence of a fairly large excess of  $\text{HCl}$ . Under these conditions no barium borate was precipitated, as was verified later by testing the precipitated  $\text{BaSO}_4$  for boric acid. A check experiment was made by estimating the total sodium (in the case of  $\text{Na}_2\text{SO}_4$ - $\text{Na}_2\text{B}_4\text{O}_7$ ) in the glass samples. A definite weight of the sample was taken in a weighed platinum crucible, treated with a mixture of pure  $\text{HF}$  and  $\text{H}_2\text{SO}_4$  and repeatedly evaporated to dryness, until a constant weight was obtained. Usually the  $\text{Na}_2\text{SO}_4$ , calculated in

this way (after allowing for sodium in  $\text{Na}_2\text{B}_4\text{O}_7$ ) tallied with the sodium sulphate calculated from  $\text{BaSO}_4$ . In this way the concentration of the alkali sulphate in the glass was calculated.

**Density determination.**—The densities of the samples were determined by a floatation method followed in a previous communication (Majumdar and Sarma, *loc. cit.*). Acetylene tetrabromide and purified toluene were the liquids used in the mixture. The usual precautions were taken regarding pyknometer, etc., and the density was determined in a transparent thermostat maintained at  $35^\circ (\pm 0.05)$ .

**Refractive Index determination.**—The refractive index of the samples was determined in D-light from an Osram Sodium lamp by the Becke method backed by a Pulfrich refractometer as described in the previous paper. The refractive index of the samples, strictly speaking, should be determined (calculated from a dispersion formula) for infinitely long wave-length in order to fit in with the theoretical considerations. But for comparative purposes, the values for a particular wave-length in the visible as with the D-light may be taken without serious error. No claim is, however, made for the accuracy of the individual values beyond the third decimal place.

In the following tables the values of density and refractive index corresponding to different compositions of the various salts are recorded.

TABLE I  
 $\text{Li}_2\text{SO}_4$ — $\text{Na}_2\text{B}_4\text{O}_7$  system

$\text{Li}_2\text{SO}_4$		Density.	n <sub>D</sub> .
%	cg/1000g.		
5.42	0.986	2.3488	1.5044
8.52	1.546	2.3468	1.4994
11.45	2.083	2.3444	1.4960
13.23	2.407	2.3480	1.4924
14.50	2.637	2.3401	1.4904

TABLE II  
 $\text{Na}_2\text{SO}_4$ — $\text{Na}_2\text{B}_4\text{O}_7$  system

$\text{Na}_2\text{SO}_4$		Density.	n <sub>D</sub> .
%	cg/1000g.		
5.87	0.8263	2.3719	1.5091
10.04	1.414	2.3821	1.5048
14.45	2.0345	2.3951	1.5007
18.13	2.5525	2.4042	1.4975
19.83	2.792	2.4072	1.4962

TABLE III  
 $\text{K}_2\text{SO}_4$ — $\text{Na}_2\text{B}_4\text{O}_7$  system

$\text{K}_2\text{SO}_4$		Density.	n <sub>D</sub> .
%	cg/1000g.		
5.94	0.6181	2.3695	1.5109
11.16	1.2810	2.3998	1.5076
17.64	2.0245	2.4167	1.5086
19.50	2.2880	2.4276	1.5028
21.56	2.4745	2.4337	1.5013



## DISCUSSION

If  $n$  be the refractive index and  $d$ , the density of a substance, then the specific refraction,  $r$  may be calculated according to the Lorenz-Lorentz formula,

$$r = \frac{n^2 - 1}{n^2 + 2} \cdot \frac{1}{d}$$

If the additivity formula holds good in the glass systems studied and if  $p$  be the percentage of the alkali sulphate and  $(100-p)$  that of the borax, then we have

$$r = p.r_1 + (100 - p).r_2,$$

where  $r_1$  and  $r_2$  are the specific refractions of the alkali sulphate and borax glass respectively. If we make the justifiable assumption that the refraction of the solvent medium remains unaltered, then we can calculate the specific refraction of the dissolved sulphate for different concentrations. The mole-refraction will be obtained by multiplying this value by the molecular weight.

In the following tables, the values of mole-refraction of the different alkali sulphates are recorded for different concentrations and compared with the values for the pure crystal and in aqueous solution at infinite dilution.

TABLE IV

System: $\text{Li}_2\text{SO}_4$ —borax glass					
$\text{Li}_2\text{SO}_4$ .	$r$ (mix) obs.	$r\text{Li}_2\text{SO}_4$ (calc.)	$R\text{Li}_2\text{SO}_4$ (calc.)	$R_{\text{sol.}}$	$R_{\text{cryst.}}$
5.42%	0.1261	0.0946	10.406	14.16	13.75*
8.52	0.1251	0.0948	10.426		
11.45	0.1243	0.09659*	10.620	(Geffeken, <i>loc cit.</i> )	
13.23	0.1239	0.0973	10.704		
14.50	0.1236	0.0984	10.82		

TABLE V

System: $\text{Na}_2\text{SO}_4$ —borax glass					
$\text{Na}_2\text{SO}_4$ .	$r$ mix(obs)	$r\text{Na}_2\text{SO}_4$ (calc.)	$R\text{Na}_2\text{SO}_4$ (calc.)	$R_{\text{sol.}}$	$R_{\text{cryst.}}$
5.869%	0.1259	0.0932	13.240	15.24	14.97*
10.04	0.1244	0.0938	13.558	(Wulff & Schaller,	
14.45	0.1228	0.0931	13.225	<i>Z. Krist.</i> , 1934,	
18.13	0.1218	0.0941	13.370	87A, 60)	
19.83	0.1214	0.0948	13.460		

TABLE VI

System: $\text{K}_2\text{SO}_4$ —borax glass					
$\text{K}_2\text{SO}_4$ .	$r$ mix(obs)	$r\text{K}_2\text{SO}_4$ (calc.)	$R\text{K}_2\text{SO}_4$ (calc.)	$R_{\text{sol.}}$	$R_{\text{cryst.}}$
5.94%	0.1263	0.1015	17.69	19.30	19.07*
11.16	0.1241	0.0940	16.38	(Wulff & Heigl,	
17.64	0.1225	0.0969	16.89	<i>Z. Krist.</i> ,	
19.60	0.1217	0.0961	16.74	1931, 77, 111)	
21.56	0.1211	0.0964	16.80		

\*These values represent the mean of those along different optical axes.

In the above calculations, the values for borax glass are taken as given below (Wulff and Majumdar, *loc. cit.*).

Borax glass	Density,	$n_D$	sp ref, ( $r_s$ )
-	2.9560	1.5148	0.1278

It is apparent from the results that in the cases of the three alkali sulphates investigated, the mole-refraction of the dissolved salt is markedly less than their values either in the pure crystal or in aqueous solution at infinite dilution. Secondly, the mole refraction-concentration curve in every case shows a positive slope. For lithium sulphate, the values of  $R$  in the crystal and at infinite dilution are respectively 13.75 and 14.16 c. c., while an increase of salt concentration from 0.99 to 2.64 g. equiv./1000g. borax causes the value to increase from 10.40 to 10.77. The same behaviour is shown more or less by the other two sulphates, namely sodium and potassium sulphates. The difference  $\Delta R (=R_{\text{cryst}} - R_{\text{glass}})$  is most pronounced in the case of lithium sulphate which is to be expected from the Fajans deformation theory.

The mutual interaction of ions in an ionic crystal is rather complicated. The resultant effect can be resolved into four individual interactions, two of which cause an increase and the remaining two a decrease in the refraction. Briefly it may be stated as follows :

Interaction of cation on anion	...	Decrease in refraction	..	(i)
" anion on cation	...	Increase " "	...	(ii)
" cation on solvent	...	Decrease " "	...	(iii)
" anion on solvent	...	Increase " "	...	(iv)

In many cases where the cation is small or highly charged, effects (i) and (iii) preponderate over (ii) and (iv). Such for example are the cases of salts like LiCl, NaCl, KCl, NaI, etc. in aqueous solutions; in every case a pronounced negative slope in the mole-refraction-concentration curve is noticeable (*cf.* Geffcken. *Z. physikal. Chem.*, 1929, B, 5, 81). On the other hand, positive slopes in the curves are obtained with salts like  $\text{Al}(\text{ClO}_4)_3$ ,  $\text{LiClO}_4$ ,  $\text{NaClO}_4$ ,  $\text{Na}_2\text{SO}_4$  etc. In these cases it must be assumed that effects (ii) and (iv) preponderate over those of (i) and (iii). That is, either the anion is hydrated, which is less pronounced in the case of anions than cations, or there is a decreased dissociation of the salt. The second alternative seems more plausible.

In a previous paper (Majumdar and Banerjee, *loc. cit.*), it has been shown that although the alkali chlorides in aqueous solutions give a negative slope in the ( $R$ -conc.) curves, the same salts dissolved in borax glass reveal pronounced positive slopes. This points to a decreased dissociation of the salts in borax glass solvent (as opposed from dissociation in aqueous solution), as with a system like  $\text{NaCl}-\text{Na}_2\text{B}_4\text{O}_7$ , the effect (iv), i.e. anion exchange with the solvent will have no significance. In the case of alkali sulphates on the other hand, the refractometric evidence reveals the existence of

undissociated molecules in concentrated aqueous solutions and the results recorded in the present paper show that in a glass medium the dissociation of the sulphates is still smaller. The result can also be expected from consideration of the low dielectric constant of the glass medium. This does not mean, however, that the electrical conductivity of these salts will be less in solution in glass than in the pure crystals. As a matter of fact we can conceive of a regular transition, so far as ionisation is concerned, from the crystal lattice to the aqueous solution, the state of solution in glass representing an intermediate stage. In one extreme we have the ions of the crystal held by strong electro-static forces, in the other, these forces are evanescent, while in solution in glass they exist in a subdued form.

The density of the dissolved salts is calculated from the additivity formula as follows :

$$d_{\text{mix}} = \frac{p.d_1 + (100 - p).d_2}{100}$$

where  $d_{\text{mix}}$  is the calculated density of the mixture,  $p$ , the percentage of the salt,  $d_1$ , the density of the pure salt and  $d_2$ , the density of borax. The following values of density of fused  $\text{Na}_2\text{B}_4\text{O}_7$  has been taken to be 2.356 and those of the salts are given in the respective tables.

TABLE VII

$\text{Li}_2\text{SO}_4$ —borax system ( $d$  for  $\text{Li}_2\text{SO}_4 = 2.221$ )

$\text{Li}_2\text{SO}_4$	$d$ obs.	$d$ mix.
5.42%	2.3488	2.3486
8.52	2.3468	2.3444
11.45	2.3444	2.3405
13.23	2.3430	2.3381
14.50	2.3401	2.3364

TABLE VIII

$\text{Na}_2\text{SO}_4$ —borax system ( $d$  for  $\text{Na}_2\text{SO}_4 = 2.605$ )

$\text{Na}_2\text{SO}_4$	$d$ obs.	$d$ mix.
5.87%	2.3719	2.3741
10.04	2.3821	2.3864
14.45	2.3951	2.4000
18.13	2.4042	2.4126
19.83	2.4072	2.4172

TABLE IX

$\text{K}_2\text{SO}_4$ —borax system. ( $d$  for  $\text{K}_2\text{SO}_4 = 2.665$ )

$\text{K}_2\text{SO}_4$ %	$d$ obs.	$d$ mix.
5.94	2.3695	2.3723
11.16	2.3983	2.3900
17.64	2.4159	2.4104
19.50	2.4276	2.4162
21.56	2.4337	2.4226

Although the variation between the calculated and observed values of the densities of the mixtures are not very pronounced (less than 1% in the maximum deviation), the following regularities are, however, noticeable. In the cases of  $\text{Li}_2\text{SO}_4$  and  $\text{K}_2\text{SO}_4$ , the observed values of density are slightly greater than the calculated values, while reverse is the case with  $\text{Na}_2\text{SO}_4$ . The increase in the observed values in the two former cases seems to support the view of Zachariasen and Warren about the structure of boric oxide and borax glasses. According to these workers, an irregular or non-periodic three dimensional network is formed inside the glass with each boron atom linked with three others through an oxygen atom in each case. A structure like the above is thus formed within the glass. In the case of borax glass it is further assumed that the  $\text{Na}^+$  ions are lodged inside the hollows of these three dimensional groupings. It may be conceived therefore that when a polar salt is dissolved in such a glass, its ions will penetrate inside the mesh and hence the observed density of the mixture will be greater than the value calculated from the additivity formula. The rival theory of crystallite formation in the glass would lead to a complete irregularity of mixing with consequent isotropy and one cannot expect any regularity in the variation of density between the observed and calculated values. Biltz who upholds the latter view has, however, explained the variation as due to the so-called "Packing effect" (Biltz, Weike and Schrader-Träger, *Z. anorg. allgem. Chem.*, 1937, 234, 282; *Glastech. Ber.*, 1938, 16, 131). The values of  $\text{Na}_2\text{SO}_4$ , however, show a decrease in the observed value. This point is being further studied.

Our best thanks are due to Prof. P. B. Sarkar of the University College of Science, Calcutta for kindly preparing a pure sample of lithium sulphate.

# MOLÉCULAR STATE OF DISSOLVED SHELLAC

BY SADHAN BASU

A systematic study of the viscometric properties of shellac in different solvents and at different temperatures has been made. It has been found that shellac dissolves molecularly in ethyl alcohol, *n*-propyl alcohol, *n*-butyl alcohol, *n*-butyric acid and ethyl lactate, at least at low concentrations of the solute. Water causes solvation of shellac in solution. In concentrated solution a definite but loose structure develops. Shellac gels show the phenomenon of gel syneresis.

Systematic investigations on the nature of shellac solutions undertaken by Palit (*J. Indian Chem. Soc.*, 1940, 17, 537) revealed, from considerations of dialysis, ultrafiltration, etc., that the previous views of Gardner (*Ind. Eng. Chem.*, 1929, 21, 227; *ibid. Anal. Ed.*, 1929, 1, 207) and of Verman (London Shellac Research Bureau, Technical paper No. 11, pp. 4, 11) regarding the colloidal nature of shellac solution could not be wholly justified. Shellac, Palit believed, dissolved molecularly in organic solvents, the observed gelation of the solution at a particular concentration and temperature being explained on the basis of solvation. He, however, did not produce any direct experimental evidence in support of the existence of solvation. With a view to throwing further light on the problem, an entirely new line of investigation, namely, a systematic study of the viscometric properties of shellac in different solvents and at different temperatures was undertaken, the results of which have been reported in the present paper.

The relation between the viscosity and the concentration of the dissolved macromolecular particles, first deduced by Einstein (*Ann. Physik*, 1906, 17, 19, 289) for rigid spheres, may be stated as

$$\frac{\eta}{\eta_0} = 1 + 2.5 \phi \dots \dots \dots (1)$$

where  $\phi$  is the ratio of the volume of the dissolved solute to that of the solvent and  $\eta, \eta_0$  are respectively the viscosity of the solution and viscosity of the solvent. Putting  $\eta/\eta_0$  as  $\eta_{rel}$  (relative viscosity) and  $\eta_{rel} - 1$  as  $\eta_{sp}$  (specific viscosity), equation (1) may be written as

$$\eta_{sp} = 2.5 \phi \dots \dots \dots (2)$$

The most general form of this equation, irrespective of particle shape, is

$$\eta_{sp} = k\phi \dots \dots \dots (3)$$

where  $k$  is a constant depending on the shape of the particle. Now  $\phi$  is proportional to concentration, hence if  $\eta_{sp}/c$  be plotted against  $c$ , the curve should be parallel to the concentration axis at least in the region of ideal dispersion. In most cases of macromolecular solutions, however, this parallelism is never realised, the curve showing a constant rise with concentration. Kraemer (*J. Phys. Chem.*, 1935, 39, 153), however, showed that if

the curve  $\eta_{sp}/c$  against  $c$  be extrapolated to zero concentration, the intercept on  $\eta_{sp}/c$  axis is a quantity characteristic of macromolecular solute in its dissolved state. This quantity, called by Kraemer, intrinsic viscosity,  $[\eta]$ , is defined as

$$[\eta] = (\eta_{sp}/c) = 0 \quad \dots \quad \dots \quad \dots \quad 4)$$

The intrinsic viscosity is very sensitive to changes in size, shape, aggregation, solvation, etc. of the particles. The degree of solvation, as also aggregation, decrease with rising temperature and consequently intrinsic viscosity may be expected to decrease with temperature. Thus from the effect of temperature on intrinsic viscosity, the physical nature of the solute in the solution can be deduced and a clear insight into the nature of the solution obtained.

Further, from the literature on the subject, it is found that solutions of high polymers show very large deviation from the classical Hagen-Poiseuille law for the flow of liquids through capillaries, for which other things remaining constant, the volume discharged in unit time through a capillary, instead of being simply proportional to pressure, increases more rapidly with increasing pressure. Two types of deviations have been observed. In one type, the liquids deviate more and more from Newtonian behaviour as the pressure is increased, and in the other, they tend to conform more and more to Newtonian behaviour under the same circumstances. Both these effects have been attributed to the existence of some sort of structure in the solution. In fact, the effect of velocity gradient on viscosity is one of the most definite indications as to the state of dispersion of the dissolved units.

#### EXPERIMENTAL

*Apparatus and Method.*—Dewaxed shellac was powdered to 100 mesh, dried at 42° for 6 hours and then kept in a vacuum desiccator over fused calcium chloride for 4 days. The same sample was used in each experiment, since the moisture content and the state of aggregation have great influence on the viscosity of shellac, especially in dilute solutions. The solvents used were thoroughly dried and twice distilled with the usual precautions.

Viscosity measurements were carried out with an Ostwald's capillary viscometer, temperature being controlled by means of a water thermostat.

Solutions were prepared by weighing out the dried shellac in conical flasks and adding the required volume of solvents from a burette. The flasks were well corked and the mixture allowed to stand 4 hours for complete dissolution. The solutions were then rapidly filtered and kept in tightly corked bottles.

The effects of different amounts of shearing stress were observed with a Bingham capillary viscometer, the pressure being applied by means of a water column. In between the viscometer and the water column was placed a calcium chloride guard tube in order to prevent entrance of moisture.

Measurements of density were carried out with a pycnometer and the partial specific volume was calculated from the equation,

$$\mathcal{V} = \frac{w - (l - h)}{\rho h}$$

where  $\mathcal{V}$  is the weight of the solvent in the pycnometer,  $l$ , the weight of solution,  $h$ , the weight of solute and  $\rho$ , the density of solvent.

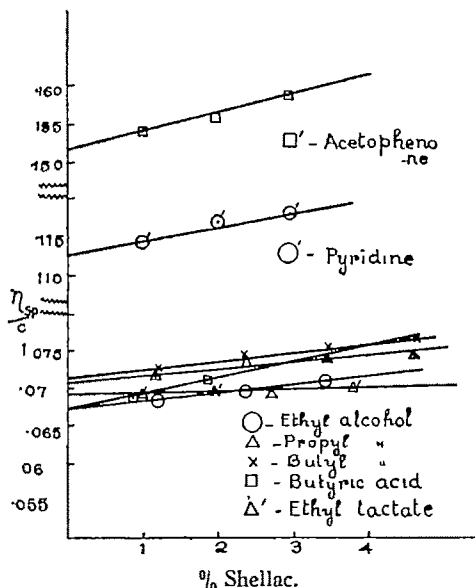
*Intrinsic Viscosity and Solvent.*—The variation of  $\eta_{sp}/c$  with  $c$  for solvents is shown in Fig. 1. The measurements were made up to 4% concentration of shellac, since within this range the  $\eta_{sp} - c$  curve is strictly linear and the partial specific volume remains substantially constant (Table I).

TABLE I

Shellac (%)	...	1	2	3	4
Partial sp. vol., (c.c.)	...	0.930	0.928	0.933	0.932

Thus from the observed linearity of  $\eta_{sp}/c$  curve, as well as from the constancy of the partial specific volume, the solution within this range may be taken as strictly dilute. Though a straight line relationship has been observed for all the solvents used (Fig. 1), the curve  $\eta_{sp}/c - c$  is not parallel to the  $c$ -axis. For three different alcohols (viz., ethyl, *n*-propyl and *n*-butyl),

Fig. 1.



the curves are nearly parallel to each other, but in the case of *n*-butyric

acid the slope is much steeper. The values of intrinsic viscosity, as obtained from an extrapolation of the curves to zero concentration, are shown in Table II.

TABLE II

Solvent.	$[\eta]$	Solvent.	$[\eta]$
Ethyl alcohol	0.0665	Ethyl lactate	0.0690
<i>n</i> -Propyl alcohol	0.0700	Acetophenone	0.1515
<i>n</i> -Butyl alcohol	0.0710	Pyridine	0.1125
<i>n</i> -Butyric acid	0.0670		

In the case of the first five solvents (Table II) the intrinsic viscosity remains practically constant, the variation being not more than 4 to 5%. But pyridine and acetophenone give values markedly different from those obtained with the five solvents mentioned above.

*Intrinsic Viscosity and Temperature.*—Various  $\eta_{sp}/c - c$  curves for different temperatures with *n*-propyl alcohol, *n*-butyric acid and ethyl lactate as solvents become more and more parallel to the *c*-axis as the temperature is raised, the curve for *n*-propyl alcohol at 60° being almost parallel to the *c*-axis. The intrinsic viscosities at three different temperatures (extrapolated from the graph) are shown in Table III.

TABLE III

Temp.	<i>n</i> -Propyl alcohol.	<i>n</i> -Butyric acid.	Ethyl lactate.
40°	0.0693	0.0668	0.0680
50	0.0665	0.0641	0.0660
60	0.0630	0.0630	0.0644

The variation of intrinsic viscosity due to 10° rise in temperature is barely 4% (Table III).

The values of  $[\eta]$  obtained from the curves  $\eta_{sp}/c - c$  at various temperatures for pyridine and acetophenone are given in Table IV.

TABLE IV

Temp.	Intrinsic viscosity $[\eta]$ for solvents		
	Pyridine.	Acetophenone.	<i>n</i> -Propyl alcohol with 5% H <sub>2</sub> O.
30°	0.1120	0.1515	—
40	0.1050	0.0950	0.0832
50	0.1000	0.0650	0.0691
60	—	—	0.0610

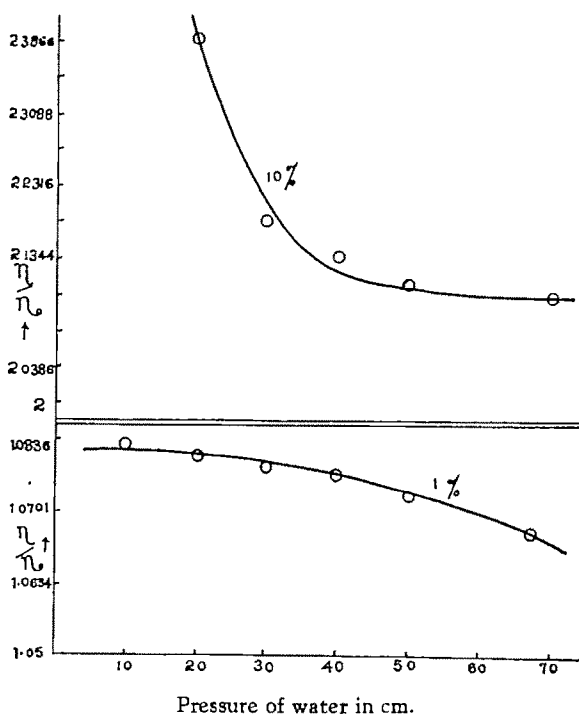
The variation of  $[\eta]$  with temperature is rather low for pyridine but quite considerable for acetophenone.

The variation of intrinsic viscosity with temperature in the case of *n*-propyl alcohol containing 5% water is shown in the last column of Table IV from which it is evident that the intrinsic viscosity at 40° is higher than that of pure *n*-propyl alcoholic solution (Table III) and the rate of variation of  $[\eta]$  with temperature is also considerable.



*Effect of Velocity Gradient.*—The effects of different shearing stresses (i.e. different velocity gradients) on  $\eta/\eta_0$  i.e. relative viscosity in ethyl alcoholic solution are shown in Fig. 2, in which  $\eta/\eta_0$  has been plotted against pressure expressed in cm. of water column. The curves for two different concentrations (1% and 10% solutions) of shellac are given. In the case of 1% solution fall in value

Fig. 2.



is rather small, becoming somewhat pronounced only at relatively high pressure. But in the case of a 10% solution there is a sharp fall with comparatively small increase in pressure, after which  $\eta/\eta_0$  gradually approaches a constant value as the pressure is increased.

*Syneresis of Gel.*—Acetophenone solution of shellac at high concentrations can form gel showing the phenomenon of gel syneresis, as previously observed by Heller (*Compt. rend.*, 1937, 43, 204; *J. Phys. Chem.*, 1941, 45, 1203; 1942, 46, 783) with the gels of ferric hydroxide, clay, etc. Thus when a 10% solution of shellac in acetophenone is prepared by warming, followed by cooling to 30°, it forms a thick gel, which on standing for 24 hours separates out into an upper sol phase and a lower concentrated gel phase. As the concentration of shellac is increased, the separation of the sol becomes less and less marked until at 40% concentration no further separation of sol and gel takes place even after 48 hours. The results are tabulated below (Table V),

TABLE V

Volume of solution taken = 20c.c.

Conc. of shellac (%)	10	20	30	40
Separation of soln (c.c.)	12	10	5	Nil

These observations were made in wide bottles. When, however, 20 c. c. of the 10% solution were kept in a narrow test tube, the sol separation did not exceed 3 c. c. after 24 hours, which however, could be increased to 10 c. c. on centrifuging. Similar observations could also be made with gels in other solvents mentioned before, but owing to the greater solubility of shellac in such solvents gelation took place only at a much higher concentration, thus making a systematic study difficult. Syneritic phenomena have also been observed with urea-shellac gel (also observed by G. N. Bhattacharya in this laboratory) and shellac gel in acetone-water mixture.

## DISCUSSION

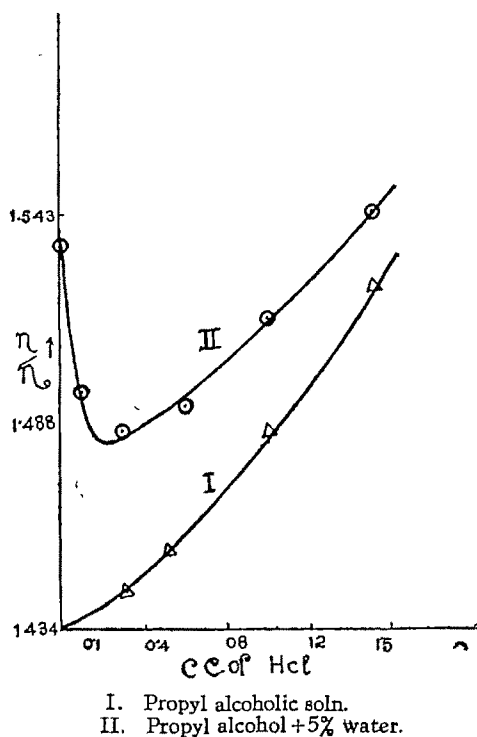
There is a considerable volume of experimental data in the literature showing, without doubt, that a large number of macromolecular solutes dissolve in many solvents to the same kinetic units. Thus the observed constancy, as well as the low temperature coefficient of intrinsic viscosity of both organic and inorganic cellulose derivatives (Kraemer, *Ind. Eng. Chem.*, 1938, 30, 1200; Sakurda and Shojino, *Kolloid Z.*, 1934, 68, 300; Kraemer and Sears, *J. Rheology*, 1931, 2, 29); Philippoff *Kautschuk*, 1938, 12, 124), led the authors to conclude that cellulose derivatives in dilute solutions dispersed to the same kinetic units. The same conclusion should apply to the first five solutions of shellac also (Table II), since it is highly improbable that these solutions, using different solvents, should contain a uniform size of the macromolecular aggregates and the same volume of solvents should be immobilised in every case. Moreover, as solvation and aggregation are very sensitive to changes of temperature, the negligible variation of  $[\eta]$  with temperature in these cases may be regarded as a further confirmation of the molecularity of shellac in solution.

Apparent anomalies observed in cases of acetophenone and pyridine solutions, for which the values of intrinsic viscosity are markedly different from the constant value obtained in case of the other solvents, may be explained as follows: In the case of acetophenone, the low solubility of shellac in this solvent and also the readiness with which the system sets to a gel at as low a concentration as 10% suggest the existence of solvation and aggregation, which is further confirmed by the enormous temperature effect on the intrinsic viscosity. The existence of structure is also indicated by the fact that even at 2% concentration vigorous shaking causes a fall in  $\eta_{rel}$  from 1.316 to 1.225 as has been actually observed showing that mechanical stress has resulted in breakdown of the structure.

The case of pyridine is somewhat different. It will be observed from Table III that though the intrinsic viscosity is higher than in the case of other solvents, the effect of temperature on it is but slight. This may be attributed to the capacity of pyridine as a base to form salt with shellac that might disperse molecularly in dilute solution. This view is further supported by the following observation. When pyridine is added drop by drop to a 5% solution of shellac in propyl alcohol, the relative viscosity rises at first and ultimately attains a constant value, a fact that also receives explanation on the same basis, namely, that at first pyridine goes to form salt with shellac, thus causing a rise in viscosity, but ultimately when the salt formation is complete, the relative viscosity remains constant (*cf.* Bhattacharya, Bulletin No. 42, Indian Lac Research Institute, 1940).

A very interesting case of variation of intrinsic viscosity with temperature has been observed with *n*-propyl alcohol-water mixture, the variation being much higher than in the case of pure *n*-propyl alcohol. An explanation for this may be found in the solvation of shellac molecules with water as postulated by Palit, for solvation may be expected to diminish with temperature and thereby cause a fall in intrinsic viscosity. Further support of this view is obtained from the effect of addition of hydrochloric acid to shellac solution. It has been shown by Harris and Nagel (*Kolloid Z.*, 1923, 55, 248) that hydrochloric acid causes agglomeration of shellac which ultimately becomes insoluble in alcohol. In Fig. 3 is shown the effect of adding 5*N*-HCl to a 5% solution of

Fig. 3.



shellac in (i) *n*-propyl alcohol and (ii) in *n*-propyl alcohol—5% water mixture. In the former case the  $\eta/\eta_0$  curve against volume of the acid rises continuously, presumably due to agglomeration. If, on the other hand, there be solvation of shellac in solution, then the effect of adding hydrochloric acid will be first to desolvate the particles and then to induce agglomeration, with the result that the curve  $\eta/\eta_0$  against volume of HCl will first show a sharp fall and then a rise with increasing concentration of the acid. This is well illustrated by curve II in Fig. 3. These facts establish beyond doubt that the particles of shellac are solvated by water in solution.

In the case of 1% ethyl alcoholic solution (Fig. 2) the effect of pressure, i.e., velocity gradient on viscosity is found to be slight in the low-pressure region, the solution behaving like a Newtonian liquid at first, but deviating from Newtonian behaviour at higher pressures. This, as proposed by Mark ("High Polymer", vol. II, p 271), is probably due to the particles being oriented during flow, the orientation being more pronounced at higher pressures. But the behaviour noticed in the case of 10% solution must be due to some other cause, namely, a change in structure arising from the mechanical stress; any structure that has been produced by the interaction of the dissolved particles, would be destroyed by stress (Freundlich and Seifriz, *Z. physikal. Chem.*, 1923, 104, 233). Hence the viscosity falls at first rapidly and ultimately assumes a constant value when the structure completely breaks down. Thus, we may assume that in a concentrated solution there is a some sort of association of the dissolved units which, however, does not proceed so far as to form a definite micelle.

Also the observed syneresis in the case of shellac gel may be interpreted on the assumption of the existence of structure in solution; of the two types of structure in solution postulated to explain syneresis, namely geloid and molecular, at lower concentration, the geloid species is unable to form close-net structure throughout the solution, and therefore settles down under the action of gravity. With increasing concentration of the solute, however, the geloid concentration progressively increases until at 40% (Table V) it is high enough to form a net-structure *en masse*. The peculiar behaviour of the solution in narrow tubes can be explained on the assumption that the gel structure is adsorbed on the surface and is thus prevented from settling down (Heller, *J. Phys. Chem.*, 1942, 46, 783). When the gel is centrifuged, the centrifugal force greatly exceeds the surfaces; consequently the gel settles down.

All these facts go to show that though shellac dissolves molecularly in dilute solutions, which are most probably swarms or loose clusters, though not definite micelle, the difference between such clusters and micelle being that the colloidal micelle is a discrete entity, whereas the clusters exist only in a statistical sense, that is to say, they continually break down on account of

thermal agitation only to re-form to an average size. Decreased thermal agitation helps to form bigger and stabler clusters and these would account for the behaviour of shellac in concentrated solution.

The author is grateful to Dr. P. K. Bose, Director, Indian Lac Research Insitute, for his kind interest and constant encouragement throughout the course of the investigation.

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# VISCOSITY AND AXIAL RATIO OF SHELLAC

BY SADHAN BASU

Molecular axial ratios for hard resin, soft resin and dewaxed shellac have been calculated from viscometric data using different solvents (EtOH, PrOH and BuOH). The ratio 10.3 for dewaxed shellac has been found to be a weighted average of the values for hard resin (11.3) and soft resin (7.8).

The effect of good and bad solvents as also of solvents-precipitant mixtures on the intrinsic viscosity of shellac and the variation of this with temperature has been studied. From a consideration of these data in the light of Alfrey, Bartovics and Mark's theory, it has been possible to conclude that shellac molecules are not flexible.

In a previous communication (Basu, this issue, p. 148) it has been shown that shellac resin dissolves molecularly in dilute solutions and further that the dissolved particles are not solvated at least up to 4% concentration. These observations make possible the calculation of molecular size of the dissolved unit from viscometric data. Accordingly, in the present paper viscometric data have been employed in determining the axial ratio, *i. e.* the ratio of length to breadth of the dissolved units.

Einstein's equation connecting the viscosity of suspensions with the size of the suspended particles, which in a sense forms the basis of the present investigation, may be written as,

$$\eta/\eta_0 = (1 + 2.5\phi) \quad \dots \quad (1)$$

where  $\eta$  is the viscosity of the solution,  $\eta_0$  that of the solvent and  $\phi$ , the volume fraction occupied by the particles in solution. This equation may be transformed into the following form

$$\eta - \eta_0/\eta_0 \text{ or } \eta_{sp} = 2.5\phi \quad \dots \quad (2)$$

The interesting point to note about this equation is that though originally intended to apply to colloidal suspensions only, it has been found to hold good for some homogeneous solutions, *e.g.*, stearic acid solution (Hollihan and Briggs, *J Phys. Chem.*, 1942, 46, 685), where the size of the solute particles is much bigger than that of the solvent. Einstein's equation, however, applies only to spherical particles and has been generalised by Sakurada (*Kolloid Z.*, 1934, 68, 2) to include cases of non-spherical particles. Sakurada's equation is

$$\eta_{sp} = K\phi \quad \dots \quad (3)$$

where  $K$  = a constant depending on the shape of the particle. The value of  $K$  can be obtained from the slope of the curves  $\eta_{sp} - \phi$ ,  $\phi$  being further defined as  $\frac{cV}{100}$ ,

where  $c$  = concentration in grams per 100 c. c. of the solvent, and  $V$  = partial specific volume of the solute.

A further attack on the problem by the hydrodynamical method, first attempted by Jeffery (*Proc. Roy. Soc.*, 1923, 102, A, 163) and later on continued by Eisenschitz (Dissertation, Vienna, 1937), Kuhn (*Kolloid Z.*, 1933, 62, 269) and others resulted in a general relation by Guth, from which Kuhn deduced as a special case the following equation

$$\eta = \eta_0 \left( 1 + \frac{5}{2} \phi + \frac{1}{16} \left( \frac{a}{b} \right)^2 \phi + \dots \right) \quad \dots \quad (4)$$

where  $a$  = half-axis major and  $b$  = half-axis minor. For a dilute solution the very small interaction between the dissolved units allows the higher terms in equation (4) to be neglected, so that it may be written as

$$\eta_{sp} = 2.5\phi + \frac{1}{16} \left( \frac{a}{b} \right)^2 \phi \quad \dots \quad (5)$$

Comparing (3) with (5) we obtain

$$K = 2.5 + \frac{1}{16} \left( \frac{a}{b} \right)^2 \quad \dots \quad (6)$$

The conditions under which Kuhn's equation should apply will be taken up in a later section.

As already stated,  $K$  may be obtained from the slope of the curve  $\eta - \phi$ , whence by using equation (6) the value of the axial ratio of the dissolved units may be calculated.

#### EXPERIMENTAL

**Apparatus and Method.**—The soft and hard resins were separated by the simple method proposed by Palit (*J. Indian Chem. Soc. Ind. & News Ed.*, 1942, 5, 25). Finely ground dewaxed shellac (100 mesh, 100 g.) was treated with 800 c. c. of 1:1 ethyl acetate-benzene mixture, allowed to stand for an hour with occasional stirring. The solution was then filtered through a piece of coarse linen. The residue was again treated with a fresh quantity of ethyl acetate-benzene mixture to free it from the adhering soft resin, and filtered after 15 to 20 minutes. The hard resin, left undissolved, was dried, dissolved in alcohol and reprecipitated with ether. Soft resin was recovered from ethyl acetate-benzene solution and dried in a vacuum oven. The analytical data for the hard resin and soft resin, thus obtained, and for the dewaxed shellac, used in the experiments, are given below.

	Ether soluble.	A. V.	Iodine value.
Dewaxed shellac	29.4%	70.3	14.14
Hard resin	2.68	64.11	12.4
Soft resin	99.06	97	15.1

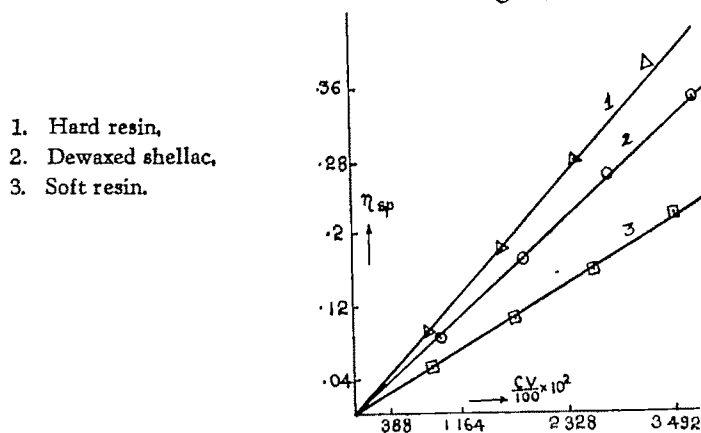
The samples were then dried by the same method as described in a previous paper (Basu, *loc. cit.*). Since complete elimination of moisture from the sample is impossible it is desirable that the absolute amount of

moisture in different solutions should be constant, to ensure a uniform variation in viscosity in every case, on account of this factor. This was attained by first preparing a concentrated mother solution which could then be diluted to required concentrations.

The viscosity measurements were carried out at 30° with an Ostwald viscometer having the inner capillary diameter of 0.8 mm. and length 6 cm. The density measurements were made with a pyknometer of 4.661 c.c. capacity.

In the previous communication (Basu, *loc. cit.*) it was shown that the partial specific volume remains constant up to a concentration of 4%. Hence the present study has been restricted to concentration up to 4% only. The specific viscosity  $\eta_{sp}$  was plotted against  $cV/100$  as shown in Fig. 1, the corresponding values being given in Table I.

Fig. 1.



1. Hard resin,
2. Dewaxed shellac,
3. Soft resin.

TABLE I

Shellac %	$\eta_{rel.}$	$\eta_{sp.}$	Solvent: Ethyl alcohol		K.	Axial ratio $a/b$ .
			Mean $V$ .	$cV/100$ .		
			Dewaxed Shellac.			
1	1.0853	0.0853		0.00930		
2	1.1712	0.1712	0.930	0.01860	9.17	10.3
3	1.2627	0.2627		0.02790		
4	1.3459	0.3459		0.03720		
			Hard Resin.			
0.8725	1.0909	0.0909		0.00815		
1.745	1.1825	0.1825	0.934	0.01630	11.03	11.7
2.6175	1.2829	0.2829		0.02445		
3.490	1.3850	0.3850		0.03260		
			Soft Resin.			
0.933	1.0554	0.0554		0.008633		
1.887	1.1051	0.1051	0.925	0.017460	6.39	7.8
2.862	1.1569	0.1569		0.026481		
3.776	1.2398	0.2398		0.034920		



The value of the axial ratio for shellac is found to be nearly a weighted average of those of hard and soft resin.

The values of the axial ratio for dewaxed shellac in two other solvents, viz., *n*-butyl alcohol and *n*-propyl alcohol are given in Table II and plotted in Fig. 2.

TABLE II

Shellac %.	$\eta$ rel.	$\eta_{sp}$ .	Solvent : Butyl alcohol.		<i>K</i> .	Axial ratio <i>a/b</i> .
			Mean V.	$cV/100$ .		
1	1.089	0.892		0.00941		
2	1.179	0.1792	0.941	0.01882	9.5	10.44
3	1.269	0.2698		0.2823		
4	1.360	0.3601		0.03764		
Solvent : <i>n</i> -Propyl alcohol						
1	1.087	0.0876		0.00938		
2	1.176	0.1767	0.938	0.01872	9.3	10.40
3	1.264	0.2645		0.02814		
4	1.353	0.3537		0.03752		

It will be seen that *a/b* ratio for dewaxed shellac in ethyl alcohol, *n*-butyl alcohol and *n*-propyl alcohol is constant within 1%.

#### DISCUSSION

Calculation of the axial ratio from viscometric data was first undertaken by Mark (*Chem. Ind.*, 1934, 31, Spec. No. 788-791) for hydrocarbons ( $C_{22}$  -) in dilute solutions. Since then Kuhn's approximate equation has been applied by Fahey and Green (*J. Amer. Chem. Soc.*, 1938, 60, 3039) to the case of glycine, casein and horse serum protein, by Lauffer (*Science*, 1938, 87, 469) and Frampton and Neurath (*ibid.*, 1938, 87, 468) to the case of tobacco mosaic virus, by Polson to a number of proteins, the last author employing also Arrhenius' equation for estimating viscosity increment at infinite dilution.

Applicability of Kuhn's equation, which depends in the first place on the persistence of a linear relationship between  $\eta$  and concentration, is limited by certain other conditions, viz., (1) *a/b* value should be small; (2) the particles should not be flexible; and (3) no solvation of the particle should take place.

(1) As to the first condition, it has been found (Eirich, *Report on Progress in Physics*, 1940, VII, 342) that for *a/b*=20, the linear relationship between  $\eta_{sp} - \phi$  does not persist beyond a very low concentration corresponding to  $\eta_{sp}=0.025$  and that for *a/b*=140, the limit of validity is reached at as low a concentration as  $c=0.015$ . In case of shellac, however, persistence of linearity at a relatively high concentration of 4% corresponding to  $\eta_{sp}=0.3459$  definitely indicates a value for *a/b*, much lower than 20, and hence the applicability of Kuhn's equation,

(2) The next point namely that shellac molecules are not flexible under the conditions of the present experiment could be tested in the light of the theory of Alfrey, Bartovics and Mark (*J. Amer. Chem. Soc.*, 1942, 64, 1667). According to this theory, in a bad solvent the segments of a flexible macromolecule attract one another, leading to a coiling up of the molecule and setting up of intramolecular agglomeration. On the other hand, for a good solvent the molecules of the solute will be surrounded in the solution by a solvent pull tending to prevent contact between the segments of the same polymer and thereby help maintain an uncurled configuration. This will result in a higher intrinsic viscosity in good solvents and a lower one in bad solvents. Further, an increase in temperature will cause curling up of the particles to approach an intermediate state, so that with a good solvent the intrinsic viscosity should decrease, while with a poor one it should increase. A valid confirmation of the above theory and the effects predicted therefrom have been obtained by Alfrey, Bartovics and Mark (*loc. cit.*) in the case of rubber, polystyrene and cellulose acetate. The contrary observation in case of shellac, namely that its intrinsic viscosity in various good solvents, (such as ethyl alcohol, *n*-propyl alcohol, *n*-butyl alcohol, *n*-butyric acid and ethyl lactate), is nearly constant and is very much lower than that in acetophenone, benzaldehyde and butyraldehyde, a number of bad solvents, indicates according to the above theory, that shellac molecules are not flexible.

Further, since it appears highly improbable that even in the various so-called good solvents the molecules will be coiled up to the same extent, the constancy of intrinsic viscosity, as well as of the axial ratio in such solvents, is an additional confirmation of the view that shellac molecules are not flexible, or more correctly, the flexibility of the molecule is negligible.

Viewed from a still another point, if a good solvent be mixed with a precipitant, the resulting mixture may be taken as less favourable to the dissolution of the particles than the pure solvent. A dilute solution of a flexible high polymer in a solvent-precipitant mixture should therefore exhibit a lower viscosity than a dilute solution of the same substance in a pure solvent. This point has been experimentally verified by the above-mentioned authors with rubber, polystyrene and cellulose acetate. In the present case the curves  $\eta/\eta_0$  (see Fig. 3) against the respective percentages of benzene and cyclohexane in a 4% solution of shellac in ethyl alcohol show that  $\eta/\eta_0$  rises continuously instead of diminishing, further supporting the view that shellac molecules are not flexible.

(3) That solvation is absent in the region of concentration studied, yet another condition to be fulfilled in applying Kuhn's equation, has been shown in a previous communication (Basu, *loc. cit.*).

Thus the three interfering factors, which might invalidate the calculation of  $a/b$  from viscometric point of view have been eliminated.

Fig. 2.

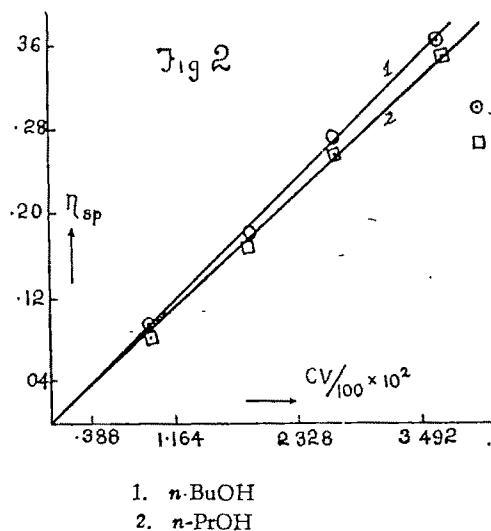
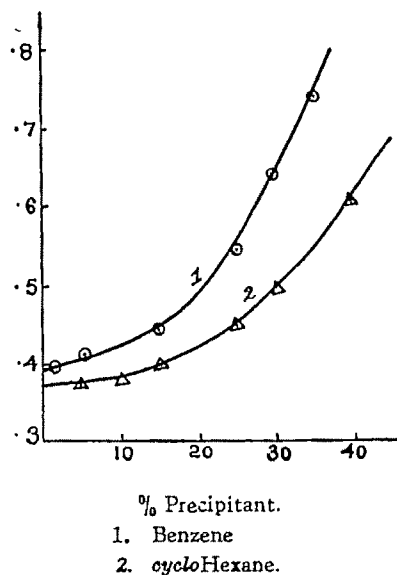


Fig. 3.



It has, however, to be remarked that all the measurements have been carried out in a capillary viscometer under high rates of shear, which might prevent free Brownian movement. This would cause the calculated  $a/b$  ratio to be greater than actual value, as could be verified in the case of tobacco mosaic virus by Frampton and Neurath (*loc. cit.*). The role of Brownian movement can be assessed only if measurements of flowing birefringence could be done with shellac solutions under identical condition. Thus the value of axial ratio obtained here cannot be taken as quantitative unless corroborated by other physical measurements viz., X-ray analysis, diffusion measurements, etc. Such diffusion measurements have been made and will be reported in a subsequent communication.

Author wishes to express his gratefulness to Dr. P. K. Bose, Director, Indian Lac Research Institute, for his kind interest and constant encouragement during the course of the work.

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# VISCOSITY OF AQUEOUS SOLUTIONS CONTAINING AN ELECTROLYTE AND A NON-ELECTROLYTE

BY T. PATNAIK AND B. PRASAD

An unsuccessful attempt has been made to find out a mixture law of viscosity for a solution containing an electrolyte and a non-electrolyte. It has been found that the viscosities of mixtures of electrolytes and non-electrolytes can be represented by the equation  $\eta/\eta_0 = 1 + A\sqrt{c} + Bc$  but the values of the constants  $A$  and  $B$  cannot be correlated with the concentration of the non-electrolyte.

The object of the work is to find an expression which would give the viscosity of a mixture containing solutions of an electrolyte and a non-electrolyte whose viscosities and concentrations in the mixture are known separately. For this purpose, succinic acid and calcium chloride have been used as the electrolyte and non-electrolyte, respectively, and the viscosities of the solutions of these two substances and of their mixtures measured by the method described by the authors (*J. Indian Chem. Soc.*, 1944, 21, 125), which are accurate within 3 in 10,000.

The results obtained are presented in Table I in which  $(\eta/\eta_0 - 1) \times 10^4$  is tabulated instead of the relative viscosity ( $\eta/\eta_0$ ) against the concentrations of succinic acid and calcium chloride in g.mols. per litre. Both  $\eta$  and  $\eta_0$  refer to 35°.

It has been found that the following relation is obeyed by mixture containing a fixed concentration of succinic acid and different concentrations of calcium chloride

$$\eta/\eta_0 = \eta' + A\sqrt{c} + Bc$$

$\eta'$  is the relative viscosity of the solution not containing any electrolyte and  $c$  is the concentration (in g. mols./litre) of the electrolyte in the mixture. The values of  $A$  and  $B$  for each set are given at the top of Table I.

The differences between the calculated and observed values of  $\eta/\eta_0$  represented as

$$D = [\eta/\eta_0(c) - \eta/\eta_0(o)] \times 10^4$$

have been calculated and are given in Table II which gives an idea of the extent to which the above equation is applicable. It is evident from Table I that the values of  $A$  and  $B$  change a good deal with a change in the concentration of succinic acid. Further, the value of  $A$  is not related to the concentration of succinic acid in any manner; in some cases it has a negative value for which no theoretical explanation can be advanced.

Although no positive contribution to the law governing the viscosity of a solution containing an electrolyte and a non-electrolyte has been made, yet

the experimental data are very accurate and could be employed with advantage by any other worker.

TABLE I

<i>A</i> ...	+0.014	-0.025	+0.015	+0.012	+0.019	+0.032	+0.05	-0.056	+0.000	
<i>B</i> ...	+0.34	+0.58	+0.27	+0.40	+0.34	+0.20	+0.08	+0.78	+0.38	
Hsuc. conc.	0.000	0.001	0.005	0.010	0.015	0.020	0.030	0.050	0.060	0.100
CaCl <sub>2</sub> conc.										
0.000	0	18	20	23	35	42	59	136	148	224
0.001	7	12	28	30	44	56	79	120	149	—
0.002	13	15	30	34	51	67	82	127	156	—
0.003	18	18	33	42	55	67	87	135	160	—
0.005	27	29	38	44	66	73	96	141	167	—
0.006	31	35	43	48	69	77	101	147	173	—
0.008	40	40	50	68	75	83	109	154	—	—
0.010	48	56	65	73	82	96	114	163	186	—
0.012	56	62	70	87	91	105	123	171	194	—
0.015	68	69	79	102	104	110	130	179	204	—
0.020	88	—	90	110	118	117	149	195	224	—

TABLE II

Values of *D*

[Hsuc] × 10 <sup>3</sup> [CaCl <sub>2</sub> ]	1	5	10	15	20	30	50	60
0.001	+4	-1	+1	0	-2	-3	+6	+3
0.002	+3	+2	+2	-1	-7	+1	0	0
0.003	+3	+3	0	0	-1	+1	-6	-1
0.005	0	+6	+8	-6	+2	+2	-6	0
0.006	-2	+5	+8	-4	+2	+1	-7	+3
0.008	-1	+5	-2	-1	+4	+1	-6	—
0.010	-5	-3	+2	+4	-2	+3	-5	0
0.012	-2	-4	-3	+5	-4	0	-3	0
0.015	+5	-8	-4	+5	+1	+2	+6	+1
0.020	—	-8	+10	+12	+10	-3	+18	0

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# STUDIES IN ADSORPTION INDICATORS. PART I. RESORCINOL SUCCINEIN AS ADSORPTION INDICATOR IN ARGENTOMETRIC TITRATIONS

BY R. C. MEHROTRA, R. D. TEWARI AND H. L. DUBE

Resorcinol succinein has been used as adsorption indicator in argentometric titrations. It has been found to be a very useful indicator and under certain conditions serves even better than fluorescein.

Following the discovery of Fajans (*Z. Electrochem.*, 1923, 29, 495), an intensive study has been made of phthaleins, sulphophthaleins, rhodamines and a few other dyes for their applicability as adsorption indicators. No attempt seems to have been made so far in applying succinic acid derivatives to these precipitation reactions. It would be of both theoretical and practical interest to try the resorcinol-succinein as an adsorption indicator.

## EXPERIMENTAL

Resorcinol-succinein was prepared by the method of Biggs and Pope (*J. Chem. Soc.*, 1923, 123, 2934) and recrystallised from acid, m. p. 234°. A solution of the pure product (1%) was made in 50% alcohol and one or two drops of the indicator employed for 10 c. c. of the solution throughout the course of this investigation.

*Titration of Chloride against Silver Ions.*—In this titration the end-point was quite sharp in *N*/10 solution, at the end-point the coagulation of the deep pink coloured precipitate occurred leaving the entire solution colourless. With the *N*/100 solutions the end-point was not so sharp. The end-point could be improved by the use of magnesium nitrate as a coagulating agent. The titration is carried out best at pH 7 using 2 drops of the indicator per 10 c. c. of the solution.

*Titration of Sulphocyanide Ions against Silver Ions.*—Coagulation of the precipitate began with the first drop of silver nitrate of *N*/10 solution and the precipitate assumed a pinkish shade from the very beginning. This observation is of interest with regard to the conflicting views of Fajans (*loc. cit.*) and Kolthoff (*Chem. Rev.*, 1935, 16, 87; *Kolloid Z.*, 1934, 68, 190). The capacity of the silver sulphocyanide particles to adsorb the succinyl fluorinate ions in presence of a large concentration of sulphocyanide ions is in accordance with the view of Kolthoff according to whom "the colour change is not due to a secondary adsorption of the dye at the active spots, but to an exchange adsorption involving lattice ions of the same electrical sign on the entire surface of the precipitate". At the end-point the colour of the precipitate changed abruptly from light pink to deep pink. The titrations of sulphocyanide can be carried out within 0.5% error up to a dilution of *N*/100. In dilute solutions, the colour change occurred in the homogeneous phase and no coagulation occurred during the course of the titration. The titrations were quite reversible.

*Titration of Bromide against Silver Ions.*—Quite sharp end-points were obtained up to 0.005 *N* solutions; with *N*/10 solutions coagulation occurred before

the end-point but the sharp colour change of the precipitate from yellow to pink occurred just at the end-point. In dilute solutions the titrations were quite reversible.

*Titration of Iodide against Silver Ions.*— $N/4000$ - KI solutions were titrated against  $N/1000$  silver nitrate with an accuracy within 1% of the theoretical amount. In  $N/10$  solutions coagulation occurred much before the end-point, but the colour change of the precipitate (pinkish yellow to deep pink) occurred just at the end-point. In dilute solution, a sharp colour change occurred in the homogeneous phase with half a drop of the silver ion in excess. When 2 drops of the indicator per 10 c. c. of the solution are used the colour change is better viewed in the reflected light. In dilute solutions, the titration was quite reversible. However, as with all other halides, the titration is not possible in acidic media.

TABLE I

Titration of	With	Dilution,	Transition.	More detailed conditions.
Cl-	Ag+	$N/10$ to $N/20$	Pink yellow soln. to pink ppt.	Soln. neutral or very weakly alkaline. Can be used with fairly high accuracy upto $N/50$ soln. In more dilute soln., the coagulating agents improve the end-point.
CN-	Ag+	$N/10$ to $N/50$	Light pink ppt. to deep pink	Coagulation occurs from the beginning, but a very sharp end-point. Soln. neutral
Br-	Ag+	$N/10$ to $N/50$	Pink yellow ppt. to pink ppt.	Coagulation occurs before the end-point, but the colour change on the ppt. appears just at the end-point. Soln. must be neutral
		$N/50$ to $N/200$	Pinkish yellow soln. to pink ppt.	Colour change occurs in the homogeneous phase and immediately after the ppt. coagulates. Titration quite reversible.
I-	Ag+	$N/10$ to $N/50$	Pink yellow ppt. to pink ppt.	Coagulation occurs much before the end-point, but a sharp colour change on the ppt. just at the end-point.
		$N/100$	Yellow soln. to pink soln.	Colour change occurs in the homogeneous phase and immediately after pinkish ppt. coagulates.
		$N/100$ to $N/4000$	Yellow soln. to pink soln.	Colour change in the homogeneous phase. Better viewed in the reflected light. Very accurate results possible with a little care.

*Comparison with fluorescein.*—The new indicator succinyl-fluorescein compares very favourably with the ordinary dye fluorescein in its applicability as adsorption indicator. Its adsorbability is definitely greater than the ordinary fluorescein. This greater adsorbability limits the range of usefulness of this indicator to  $N/10$  solutions in the case of chloride ions, but makes it a definitely better indicator for iodide ions where solutions varying from  $N/10$  to  $N/4000$  can be titrated. The end-point is particularly sharp and quite reversible in dilute solutions, because no signs of coagulation occur there and the colour change appears in the homogeneous phase.

Further work with the indicator is in progress.

The authors wish to thank Dr. J. D. Tewari for his kind interest in the present investigation.

## A NOTE ON KJELDAHL DISTILLATION IN A CLOSED STILL

BY RAM CHAND

The results of the estimation of nitrogen by Kjeldahl method are usually not concordant. One of the reasons is that ammonia evolved in the process is not completely absorbed in the acid. It is seen that the longer the period for which the ammonia remains in contact with the absorbing acid, the better the results. To elucidate this problem, a series of tests has been carried out in (a) closed still and (b) open stills. A comparative study of the two methods has been carried out, and the efficiency of the different absorbing liquids has also been studied.

Strong acids are commonly used for absorbing the ammonia. Fairly accurate results are obtained with an open type of distillation apparatus, but in this case two standard solutions are required.

Winkler (*Z. angew. Chem.*, 1913, 26, 231) has introduced the use of boric acid solution for the absorption of ammonia in open still which gives nearly as accurate results as normal sulphuric acid. Boric acid solution has the advantage that it may not be measured very accurately, and only one standard solution (for titration) is required. The difficulty of judging the end-point with methyl red or congo red has been overcome by Scales and Harrison (*Ind. Eng. Chem.*, 1920, 12, 350,) by the use of bromophenol blue. Spears (*J. Assoc. Off. Agric. Chem.*, 1921, 5, 105) and Markley and Hann (*ibid.*, 1925, 8, 455) have also reported favourably on the use of boric acid for absorbing ammonia. Stover and Sandini (*Ind. Eng. Chem. Anal. Ed.*, 1931, 3, 240) have recommended the use of boric acid solution for absorbing ammonia even in nitrogen determination by Pregel's micro-Kjeldahl method and suggest the use of mixed indicator, methyl red-tetrabromophenol blue. Eisner, Abner and Wagner (*ibid.*, 1934, 6, 473) and Meeker and Wagner (*ibid.*, 1933, 5, 396) have suggested further improvements in the use of boric acid.

Very recently Bradley (*ibid.*, 1942, 14, 705) has suggested the use of water in closed system for absorbing ammonia and has shown that this system gives quite good results. There is, however, one practical difficulty in using water *i. e.* a very large quantity of water is required which cannot be contained in an apparatus of ordinary size.

In the present work the efficiency of the two systems of distillation—the open system in which the gases are allowed to escape and the closed system in which the gases are not allowed to escape, has been extended for the selection of the best solvent for the closed system.

The closed still was made by using a filtration flask as a receiver and closing its side arm with a balloon as described by Bradley (*loc. cit.*) and out of



400 c.c. of solution in Kjeldahl flask about 250 c.c. of the solution were recovered in an hour or 45 minutes. The flask was disconnected after the distillation but the receiving flask and the balloon were allowed to remain as such for some time longer to allow more time for the absorption of ammonia.

In excess acid method and with water, methyl red was used as indicator with the slight improvement that freshly boiled distilled water ( $\text{CO}_2$  free) was always used. With boric acid solution a standard control solution was used to match the colour with methyl red as indicator. Colour matching presented no difficulty and no special light was used. The matching of colour was necessary due to the colour changes being gradual. It requires a little practice to perceive these colour changes. This indicator was found to be as accurate as some of the mixed indicators recommended by Stover and Sandin (*loc. cit.*) and Meeker Wagner (*loc. cit.*). In the table below are given the results obtained.

Absorbent.	Open stil old type.		Closed stil	
	Average recovery.	No. of estima- tions,	Average recovery.	No. of esti- mations.
Sulphuric acid	99.90	6	99.95	12
Boric acid	99.71	10	99.85	12
Water	99.06	10	99.85	12

From the table it is clear that the closed system gives far better results than the open system, irrespective of the solvent used. Boric acid gives as good results as sulphuric acid with the advantage that only one standard solution is required. The results with water are fairly within experimental error. But boric acid combines in itself the simplicity of operation of water and accuracy of the results of sulphuric acid.

## A NEW SYNTHESIS OF PYRENE

BY NRIPENDRA NATH CHATTERJEE, AMALENDU BOSE AND  
HITENDRA BHUSAN ROY

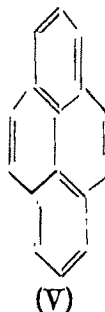
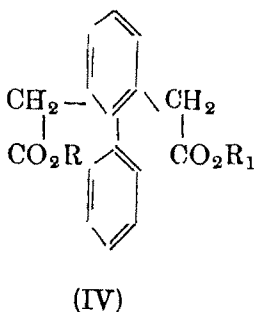
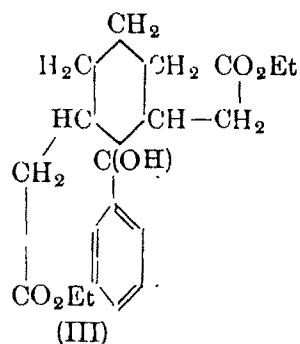
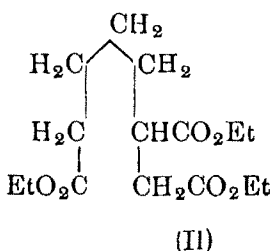
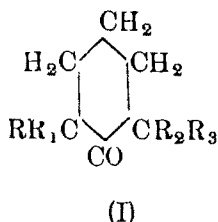
A new synthesis of pyrene is described in the present communication.

A new synthesis of pyrene which will be an useful supplement to the existing methods (Weitzenbock, *Monatsh*, 1913, 34, 193; Freund and Fleischer, *Annalen*, 1914, 402, 77; Fleischer and Retze, *Ber.*, 1922, 55, 3280; Braun and Rath, *Ber.*, 1928, 61, 956; Cook *et al.*, *J. Chem. Soc.*, 1934, 365) and which will be useful in the synthesis of pyrene derivatives having carcinogenic activity is described in the present communication.

Diethyl *cyclohexanone*-2-carboxylate-2-acetate (I,  $R_1 = R = H$ ;  $R_2 = CO_2Et$ ;  $R_3 = CH_2.CO_2Et$ ) obtained from ethyl *cyclohexanone*-2-carboxylate and ethyl chloroacetate is transformed by boiling alcoholic sodium ethoxide into ethyl 6-carbethoxycyclohexanone-2-acetate (I,  $R = R_3 = H$ ;  $R_1 = CO_2Et$ ;  $R_3 = CH_2.CO_2Et$ ), the mechanism being obviously alcoholysis and ring-closure in a new position. A second acetic acid residue is then introduced in the usual manner to yield diethyl 6-carbethoxycyclohexanone-2:6-diacetate (I,  $R_1 = R_3 = CH_2.CO_2Et$ ;  $R = CO_2Et$ ;  $R_2 = H$ ). This ester on hydrolysis yields *cyclohexanone*-2:6-diacetic acid (I,  $R_1 = R_2 = H$ ;  $R = R_3 = CH_2.CO_2H$ ). It is esterified and treated with phenyl magnesium bromide when diethyl 1-phenylcyclohexanol-2:6-diacetate (III) is obtained. The above ester on dehydration and dehydrogenation yields diethyl diphenyl-2:6-diacetate (IV,  $R = R_1 = Et$ ). Diphenyl-2:6-diacetic acid (IV,  $R = R_1 = H$ ), obtained on hydrolysing the above ester, yields a gummy product on ring-closure. Pyrene (V) is obtained from this gummy product on distillation with zinc dust.

For the synthesis of ethyl 6-carbethoxycyclohexanone-2-acetate by another method, diethyl *cyclohexanone*-2-carboxylate-2-acetate is treated with sodium ethoxide when ethyl hexane-1:2:6-tricarboxylate (II) is obtained (corresponding acid is obtained on hydrolysis). When this ester is treated with sodium in benzene, the desired ester (I,  $R = R_2 = H$ ;  $R_1 = CO_2Et$ ;  $R_3 = CH_2.CO_2Et$ ) is obtained in poor yield. The ester (I,  $R_1 = R_3 = CH_2.CO_2Et$ ;  $R = CO_2Et$ ;  $R_2 = H$ ) is also

obtained from ester (II) in poor yield by Dieckmann reaction and subsequent treatment with ethyl chloroacetate.



The synthesis of methylpyrenes by the above process is in progress and will be communicated in due course.

### EXPERIMENTAL

*Diethyl cyclohexanone-2-carboxylate-2-acetate.*—(i). Ethyl *cyclohexanone-2-carboxylate* (25 g.) was added to a solution of sodium (3.4 g.) in alcohol (31 c.c.) and the solid sodium salt was heated under reflux for 6 hours with ethyl chloroacetate (19 g.). After dilution the condensation product was extracted with ether, the ether removed and the product distilled at 168-175°/11 mm., yield 18 g.

(ii). A solution of sodium ethoxide from sodium (3.4 g.) in alcohol (83 c.c.) was slowly added with shaking to a mixture of ethyl *cyclohexanone-2-carboxylate* (25 g.) and bromoacetic ester (26 g.), absolute alcohol (50 c.c.) and sodium iodide (0.3 g.), with cooling in a bath of ice-cold water. The reaction was allowed to proceed at room temperature for 2 hours, and after refluxing for further 2 hours, the greater part of alcohol was evaporated. The residue was poured in ice-water (1000 c.c.) and the precipitated oil isolated by means of ether. The ethereal extract was washed with water, dried and the solvent removed, and it was then distilled, b. p. 168-175°/11 mm., yield 20 g.

(iii). Finely divided metallic sodium (3.4 g.) in dry benzene (120 c.c.) was slowly treated with ethyl *cyclohexanone-2-carboxylate* (25 g.) and kept overnight. Ethyl chloroacetate (19 g.) was then added and the mixture refluxed on the water-bath for 6 hours. It was then cooled, washed with water, dried over calcium

chloride and the benzene removed. The residual oil distilled at 168-175°/11 mm, yield 24 g. (Found : C, 60.9 ; H, 7.76. Calc. for  $C_{18}H_{20}O_5$  : C, 60.9 ; H, 7.8 per cent).

*Ethyl Hexane-1 : 2 : 6-tricarboxylate*.—Diethyl cyclohexanone-2-carboxylate-2-acetate (27 g.) was mixed with sodium ethoxide (Na, 0.5 g. and absolute alcohol, 11 c.c.) and heated on the water-bath for 2½ hours. The cooled solution was poured into a mixture of ether and water, and ethereal extract separated, washed with water and dried and the ether removed. The triethyl ester had b. p. 183°/8 mm., yield 21 g. (Found : C, 59.7 ; H, 8.32.  $C_{15}H_{26}O_6$  requires C, 59.6 ; H, 8.6 per cent).

*Hexane-1 : 2 : 6-tricarboxylic Acid*.—Ethyl hexane-1 : 2 : 6-tricarboxylate (10 g.) was refluxed with boiling concentrated hydrochloric acid (25 c.c., 4 hours) and the acid isolated by removal of the mineral acid under reduced pressure was crystallised from a mixture of ethyl acetate and petroleum ether, m. p. 90°. (Found : C, 49.7 ; H, 6.8.  $C_8H_{14}O_6$  requires C, 49.5 ; H, 6.4 per cent).

*Ethyl 6-Carbethoxycyclohexanone-2-acetate*.—Ethyl hexane-1 : 2 : 6-tricarboxylate (19 g.) was heated on the water-bath with molecular sodium (3 g.) in dry benzene (50 c.c.) for 1 hour to start the reaction. Heating was then continued for further 1 hour. After the addition of alcohol (10 c.c.) and water to the cooled reaction mixture, the solution was acidified with dilute hydrochloric acid, ether added, the ether separated, washed with sodium carbonate solution, then with water and dried, and the solvent removed. The keto-ester (5 g.), b. p. 169-170°/5 mm. gives a deep violet coloration with ferric chloride. (Found : C, 61.4 ; H, 7.64.  $C_{13}H_{20}O_5$  requires C, 60.9 ; H, 7.8 per cent).

*Ethyl 6-Carbethoxycyclohexanone-2-acetate*.—A mixture of diethyl cyclohexanone-2-carboxylate-2-acetate (48 g.) and alcoholic sodium ethoxide (48 g. Na and 70 c.c. alcohol) was refluxed for 8 hours on the sand-bath. The product was treated with ice-cold dilute sulphuric acid and extracted by means of ether and after removing the ether it was collected at 169-170°/5 mm. It gives deep violet coloration with alcoholic ferric chloride solution, yield 30 g. (Found : C, 60.6 ; H, 8.1.  $C_{13}H_{20}O_5$  requires C, 60.9 ; H, 7.8 per cent).

*Diethyl 6-Carbethoxycyclohexanone-2 : 6-diacetate*.—Ethyl hexane-1 : 2 : 6-tricarboxylate (23 g.) was refluxed with molecular sodium (3.5 g) for 3 hours in benzene (75 c.c.). After it was cooled, ethyl chloroacetate (20 c. c.) was added and refluxing continued for 6 hours. After working up in the usual manner, it was collected at 190°/4 mm., yield 12 g. (Found : C, 59.9 ; H, 7.4.  $C_{17}H_{26}O_7$  requires C, 59.65 ; H, 7.6 per cent).

*Diethyl 6-Carbethoxycyclohexanone-2 : 6-diacetate*.—Ethyl 6-carbethoxycyclohexanone-2-acetate (48 g.) was added to a suspension of sodium powder (54 g.) in benzene (100 c.c.). The solution of the sodium was completed by refluxing for 2 hours. The orange liquid was cooled and ethyl chloroacetate (24 g.) introduced. The mixture was refluxed for 5 hours ; no solid, however, separated from the slightly turbid solution. The reaction product was mixed with water and a few drops of hydrochloric acid, and the ester was isolated by means of ether. The ethereal extract

was washed with water, dried and the solvent removed. It was then collected at  $190^{\circ}/4$  mm., yield 25 g. (Found : C, 59.7 ; H, 7.42.  $C_{17}H_{26}O_7$  requires C, 59.65 ; H, 7.6 per cent).

*cycloHexanone-2:6-diacetic Acid*.—A mixture of diethyl 6-carbethoxy-*cyclohexanone-2 : 6-diacetate* (25 g.) and concentrated hydrochloric acid (200 c.c.) was refluxed for 1 hour, and the clear solution was then evaporated under reduced pressure. The residue crystallised and the solid was collected, washed with saturated aqueous ammonium sulphate and then with a little water, dried at  $100^{\circ}$ , and crystallised from a mixture of ethyl acetate and petroleum, m. p.  $188^{\circ}$ , yield 9 g. (Found : C, 56.46 ; H, 6.8 ; Equiv., 107.  $C_{10}H_{14}O_5$  requires C, 56.1 ; H, 6.54 per cent. Equiv., 107).

*Diethyl cycloHexanone-2 : 6-diacetate*.—The above acid (10 g.) was esterified by means of alcohol (50 c.c.) saturated at  $0^{\circ}$  with hydrogen chloride. It was kept overnight and then refluxed for 7 hours. After dilution it was extracted with ether. The ether solution was washed with sodium carbonate, water and dried. After removing ether, the di-ester was collected at  $170-175^{\circ}/6$  mm., yield 8 g. (Found : C, 62.4 ; H, 8.3.  $C_{14}H_{22}O_5$  requires C, 62.2 ; H, 8.15 per cent).

*Diethyl 1-Phenylcyclohexanol-2 : 6-diacetate*.—Phenyl magnesium bromide (from 1.5 g. of magnesium and 7.5 g. of bromobenzene in 30 c.c. dry ether) was added drop by drop to a cooled ethereal solution of diethyl *cyclohexanone-2 : 6-diacetate* (12 g., 30 c.c. dry ether) and the mixture left overnight. The product was decomposed with dilute sulphuric acid and extracted with ether. The ethereal extract was washed with water, dried over sodium sulphate and the ether removed. It was then collected at  $205-215^{\circ}/3$  mm., yield 3 g. (Found : C, 69.4 ; H, 7.7.  $C_{20}H_{28}O_5$  requires C, 69.0 ; H, 8.0 per cent).

*Diphenyl-2 : 6-diacetic Acid*.—Diethyl 2-phenyl*cyclohexanol-2 : 6-diacetate* (5 g.) was dehydrogenated by heating with calculated quantity of sulphur at  $200-250^{\circ}$  for 4 hours. The product was taken in ether and washed by means of alkali, and after removing the solvent it was heated in benzene solution for 4 hours in presence of precipitated copper. The resulting ester, obtained after working up in the usual manner, distilled at  $200-205^{\circ}/3$  mm. It was hydrolysed by means of alcoholic potash and the acid, obtained on acidifying the alkaline solution, was crystallised from dilute alcohol, m.p.  $168^{\circ}$ . (Found : C, 71.0 ; H, 5.9.  $C_{16}H_{14}O_4$  requires C, 71.1 ; H, 5.18 per cent).

*Pyrene*.—The above acid (4 g.) was converted into its chloride by boiling with thionyl chloride (40 c.c.), excess of thionyl chloride being then removed on the water-bath under reduced pressure. An ice-cold carbon disulphide (40 c.c.) solution of the chloride was treated with anhydrous aluminium chloride (4.2 g.) kept at  $0^{\circ}$  for 3 hours. The non-acidic gummy product obtained after working up in the usual manner did not solidify when kept in a vacuum desiccator, but on distillation with zinc dust yielded pyrene, m.p.  $150^{\circ}$  (mixed m.p.  $150^{\circ}$ ).

# STUDIES IN SULPHANILAMIDES. PART XIII. REACTION WITH DICARBOXYLIC ACIDS. SOME NEW N<sup>1</sup>- AND N<sup>4</sup>-ACYL AND HETEROCYCLIC DERIVATIVES \*

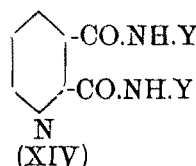
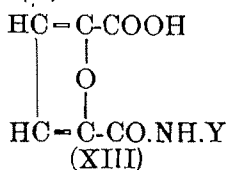
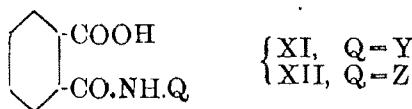
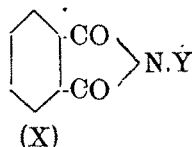
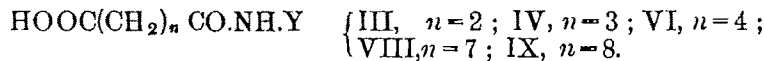
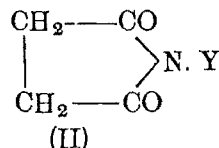
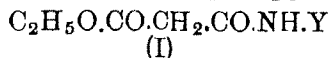
BY B. C. JAIN, B. H. IYER AND P. C. GUHA

Fourteen N<sup>1</sup>-acyl, two N<sup>4</sup>-acyl and five N<sup>1</sup>-heterocyclic derivatives of sulphanilamide are described.

Although N<sup>1</sup>-mono-acyl derivatives of sulphanilamide (Crossley *et al.*, *J. Amer. Chem. Soc.*, 1939, 61, 2950) have been prepared from aliphatic, aromatic and heterocyclic monocarboxylic acids, little information is available about diacyl compounds. In an effort to obtain diacylsulphanilamides of the type R : (CONH-C<sub>6</sub>H<sub>4</sub>.NH<sub>2</sub>)<sub>2</sub>, where R stands for aliphatic, aromatic or heterocyclic residue, the reaction of the potassium salt of *p*-acetaminobenzene sulphonamide, sulphanilamide or *p*-acetaminobenzene sulphochloride, as the case may be, has been studied with the di-acid chlorides of (a) oxalic, (b) malonic, (c) succinic, (d) glutaric, (e) adipic, (f) azelaic, (g) sebacic, (h) phthalic, (i) furan-2 : 5-dicarboxylic and (j) quinolinic acids, as also with (k) diethyldihydrocollidine dicarboxylate, (l) chelidonic acid, and (m) chelidamic acid.

Contrary to expectations, the action of the potassium salt of acetyl-sulphanilamide on the di-acid chlorides of (c), (d), (e), (f), (g), (h) and (i) led to the formation of only the N<sup>1</sup>-mono-acyl-N<sup>4</sup>-acetylsulphanilamides, (III), (IV), (VI), (VIII), (IX), (XI) and (XIII) respectively, with the second COOH group of the addendum remaining free. Condensation of the di-acid chlorides with acetyl-sulphanilamide could not be effected, although tried under various conditions. The products from the reaction with oxalyl and malonyl chlorides could not be isolated. α-Carbethoxy-N<sup>1</sup>-acetyl-N<sup>4</sup>-acetylsulphanilamide (I) has, however, been prepared by the action of the potassium salt of acetylsulphanilamide on ClOC.CH<sub>2</sub>.CO.O.C<sub>2</sub>H<sub>5</sub>, but it breaks on hydrolysis into sulphanilamide and malonic acid.

[In all the formulae in this paper, Y, stands for -SO<sub>2</sub>.C<sub>6</sub>H<sub>4</sub>.NH.CO.CH<sub>3</sub> and Z, stands for -SO<sub>2</sub>.C<sub>6</sub>H<sub>4</sub>.NH<sub>2</sub>.]

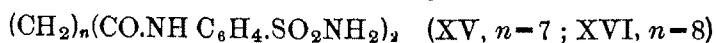


In the case of succinyl and phthalyl chlorides, it has been possible to isolate the corresponding imides (II) and (X), which on treatment with dilute alkali in the cold give N<sup>1</sup>-succinyl-N<sup>4</sup>-acetylsulphanilamide (III) and N<sup>1</sup>-phthalyl-N<sup>4</sup>-acetylsulphanilamide (XI) respectively.

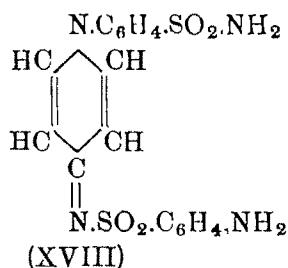
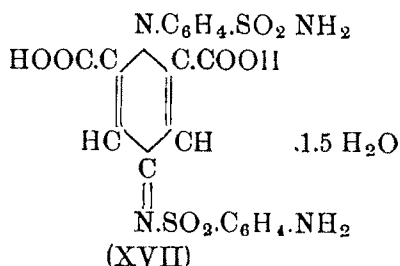
It is interesting to note that the action of (f) on the potassium salt of *p*-acetaminobenzene sulphonamide gives N<sup>1</sup>-pyridine-2 : 3-dicarbo-N<sup>4</sup>-acetyldisulphanilamide (XIV).

While N<sup>1</sup>-glutaryl- (V), N<sup>1</sup>-adipyl- (VII) and N<sup>1</sup>-phthalyl-sulphanilamide (XI) can be obtained by hydrolysis of the corresponding N<sup>1</sup>-acyl-N<sup>4</sup>-acetylsulphanilamides (IV), (VI), and (XI) respectively, hydrolysis of N<sup>1</sup>-succinyl-, N<sup>1</sup>-azelayl-, N<sup>1</sup>-sebacyl-, N<sup>1</sup>-2-carboxyfuran-5-carbo-N<sup>4</sup>-acetylsulphanilamides and N<sup>1</sup>-pyridino-2 : 3-dicarbo-N<sup>4</sup>-acetyldisulphanilamide (III, VIII, IX, XIII and XIV) respectively leads to their cleavage.

Azelaic and sebacic acid chlorides have also been condensed with sulphanilamide to get the corresponding N<sup>4</sup>-azelayldisulphanilamide (XV) and N<sup>4</sup>-sebacyl-disulphanilamide (XVI), which have not been reported so far.



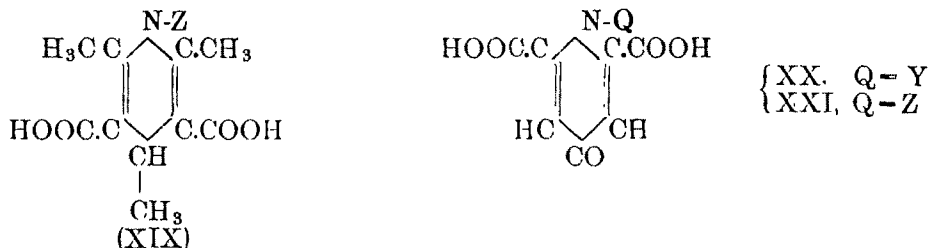
Curiously enough, the keto and pyrone oxygens and not the carboxy groups of chelidonic acid react with sulphanilamide giving N-*p*-sulphonamidophenyl-4-(*p*-aminobenzene sulphonimino)-chelidamic acid (XVII). This is due to the basic nature of the keto oxygen and the easy replaceability of pyrone oxygen by ammonia and amines as observed by Collie (*J. Chem. Soc.*, 1904, 85, 971) and Bedekar *et al.* (*J. Indian Chem. Soc.*, 1935, 12, 468).



The structure of (XVII) has been established from (i) a study of its properties, (ii) from the estimation of N, S, and NH<sub>2</sub> group and (iii) from the determination of its equivalent weight. It dissolves with effervescence in bicarbonate solution indicating the presence of free carboxyl groups. Its solubility in dilute hydrochloric acid and diazotizability prove the presence of free NH<sub>2</sub> group. The product (XVII) contains 1.5 moles of water of crystallisation which, along with 2 molecules of carbon dioxide, are eliminated when it is heated at 100-120° for 2 hours, leading to the formation of N-*p*-sulphonamidophenyl-4-(*p*-aminobenzene sulphonimino)-1 : 4-dihydropyridine (XVIII).

Fusion of *p*-acetaminobenzene sulphochloride and diethyldihydrocollidine dicarboxylate gives N-(N<sup>1</sup>-sulphonyl)-dihydrocollidine dicarboxylic acid (XIX) by

the elimination of HCl and simultaneous hydrolysis of acetyl and ester groups as is evident by the formation of ethyl acetate as one of the products of reaction.



Action of *p*-acetaminobenzene sulphochloride with chelidamic acid in dry pyridine gives N-(N<sup>1</sup>-acetsulphanilyl)-chelidamic acid (XX) which is hydrolysed to N-(N<sup>1</sup>-sulphanilyl)-chelidamic acid (XXI).

All the compounds and their analytical data are tabulated in Table I.

### EXPERIMENTAL

Compounds (I), (II), (III), (IV), (VI), (VIII), (IX), (X), (XI), (XIII) and (XIV) were prepared by the action of the appropriate acid chloride on the K-salt of acetylsulphanilamide. A typical experiment is detailed here.

**N<sup>1</sup>- $\alpha$ -Carbethoxyacetyl-N<sup>4</sup>-acetylsulphanilamide (I).**—K-salt of acetylsulphanilamide (5 g.) and the acid chloride of monoethyl ester of malonic acid (3 g.) were heated on a water-bath for 1 hour. The product was freed from the reactants by successive treatment with benzene and water and finally crystallised from alcohol, m. p. 159° (decomp.) yield, 5.2 g.

The products of hydrolysis (V, VII, XII and XXI) were obtained by treating the corresponding acetamino derivative with dilute alkali. A typical experiment is detailed below.

**N<sup>1</sup>-Glutarylsulphanilamide (V).**—N<sup>1</sup>-Glutaryl-N<sup>4</sup>-acetylsulphanilamide (IV, 2 g) was refluxed with 16% KOH solution (15 c. c.) for 3 hours and the product isolated by neutralising the norit-treated alkaline filtrate with acetic acid. The product is soluble in boiling water and alcohol as also in dilute HCl and alkali, m. p. 187°, yield 1.3 g

The reaction between sulphanilamide and the di-acid chlorides of azelaic and sebacic acids was carried out as follows.

**N<sup>4</sup>-Azelayldisulphanilamide (XV<sup>1</sup>).**—Sulphanilamide (3.5 g.) was dissolved in a mixture of pyridine (6 c.c.) and acetone (10 c.c.) and to this azelayl chloride (2.3 g.) was added gradually under ice-cooling. After keeping for  $\frac{1}{2}$  hour, the reaction mixture was refluxed on a water-bath for 30 minutes and then poured into cold acidulated water (100 c.c.). The colourless product separating was collected and crystallised from pyridine-water mixture, m.p. 251° (decomp.), yield 4.2 g.

Compounds (XVII—XX) were prepared as follows.

**N-*p*-Sulphonamidophenyl-4-(*p*-aminobenzene sulphonimino)-chelidamic Acid (XVII).**—Sulphanilamide (5.1 g., 50% excess) was added to a solution of chelidonic acid (2 g.) in water (25 c.c.) and refluxed for 2 hours during which period the solution became crimson red. As no precipitate came out on cooling, the solution was concentrated on a water-bath to half its bulk. After filtering out the unreacted sulphanilamide, which had separated out on cooling, the filtrate was again concentrated to a syrupy consistency. When alcohol was added to this, the product came out as fine colourless precipitate. Being very soluble in water, the product was purified by treating its aqueous solution with norit, filtering and concentrating and then precipitating with alcohol. It is sparingly soluble in alcohol, acetone and ethyl acetate and insoluble in benzene, m.p. 165°, yield 3.1 g.



*N-p-Sulphonamidophenyl-4-(p-aminophenylsulphonimino)-1 : 4-dihydropyridine* (XVIII).—The above compound (XVII, 1g.) was first heated at 100° for 10 minutes and then at 160° for 45 minutes. At about 110° the substance fused and frothed. After cooling, the product, insoluble in water, was purified by dissolving in alkali and precipitating with HCl, m.p. 210°, yield 0.6g.

*N-(N<sup>1</sup>-Sulphanilyl)-dihydrocollidine Dicarboxylic Acid* (XIX).—Diethyl dihydrocollidine dicarboxylate (4.2 g.) and *p*-acetaminobenzene sulphonyl chloride (4.8 g) were heated together at 130-135° for 1 hour. Reaction started at 120° with evolution of HCl and later, ethyl acetate was formed. The product was isolated and crystallised from a large volume of alcohol, m. p. 300° (decomp), yield 6.4 g.

*N-(N<sup>1</sup>-Acetylsulphanilyl)-chelidamic Acid* (XX).—To chelidamic acid (2 g.), suspended in dry pyridine (15 c.c.), *p*-acetaminobenzene sulphochloride (2.5 g.) was added with shaking and refluxed on a sand-bath for 2 hours. After cooling, the product was filtered out and washed with a little alcohol. It was crystallised from water, m.p. 227°, yield 3.2 g.

*Equivalents*.—The compounds were titrated to phenolphthalein end-point and required one equivalent of alkali for the sulphonamido group and one equivalent, for the acid group, wherever present.

TABLE I

No.	Formula.	M.p.	% Nitrogen		Equivalent	
			Found	Calc.	Found.	Calc
I.	C <sub>13</sub> H <sub>16</sub> O <sub>6</sub> N <sub>2</sub> S	1590 (d)	8.72	8.53	325.5	328.0
II.	C <sub>12</sub> H <sub>12</sub> O <sub>5</sub> N <sub>3</sub> S	259	9.36	9.50	—	—
III.	C <sub>13</sub> H <sub>14</sub> O <sub>6</sub> N <sub>2</sub> S	195	9.14	8.92	155.3	157.0
IV.	C <sub>13</sub> H <sub>16</sub> O <sub>6</sub> N <sub>2</sub> S	255 (d)	8.60	8.54	166.0	164.0
V.	C <sub>11</sub> H <sub>14</sub> O <sub>5</sub> N <sub>2</sub> S	187	10.00	9.80	140.0	143.0
VI.	C <sub>14</sub> H <sub>18</sub> O <sub>6</sub> N <sub>2</sub> S	260 (d)	8.24	8.18	170.4	171.0
VII.	C <sub>12</sub> H <sub>16</sub> O <sub>5</sub> N <sub>3</sub> S	170	9.00	9.33	152.8	150.0
VIII.	C <sub>17</sub> H <sub>24</sub> O <sub>6</sub> N <sub>2</sub> S	245	7.44	7.26	192.7	192.0
IX.	C <sub>8</sub> H <sub>10</sub> O <sub>6</sub> N <sub>2</sub> S	250 (d)	7.21	7.00	198.4	199.0
X.	C <sub>16</sub> H <sub>14</sub> O <sub>5</sub> N <sub>3</sub> S	295	8.15	8.12	—	—
XI.	C <sub>16</sub> H <sub>14</sub> O <sub>6</sub> N <sub>2</sub> S	304	7.58	7.73	180.2	181.0
XII.	C <sub>14</sub> H <sub>12</sub> O <sub>5</sub> N <sub>3</sub> S	335	8.52	8.75	168.3	160.0
XIII.	C <sub>14</sub> H <sub>12</sub> O <sub>7</sub> N <sub>2</sub> S (a)	230 (d)	7.91	8.00	177.4	176.0
XIV.	C <sub>23</sub> H <sub>21</sub> O <sub>8</sub> N <sub>6</sub> S <sub>2</sub> (b)	308	12.37	11.52	—	—
XV.	C <sub>21</sub> H <sub>28</sub> O <sub>6</sub> N <sub>4</sub> S <sub>4</sub>	251 (d)	11.80	11.31	—	—
XVI.	C <sub>2</sub> H <sub>30</sub> O <sub>6</sub> N <sub>4</sub> S <sub>2</sub>	238 (d)	10.68	10.98	—	—
XVII.	C <sub>19</sub> H <sub>16</sub> O <sub>8</sub> N <sub>4</sub> S <sub>2</sub> · 1½ H <sub>2</sub> O (c)	185	10.70	10.80	258.4	259.5
XVIII.	C <sub>17</sub> H <sub>16</sub> O <sub>4</sub> N <sub>4</sub> S <sub>2</sub> (e)	210	13.62	13.86	—	—
XIX.	C <sub>16</sub> H <sub>16</sub> O <sub>6</sub> N <sub>2</sub> S (f)	300 (d)	7.62	7.65	152.5	153.0
XX.	C <sub>15</sub> H <sub>12</sub> O <sub>8</sub> N <sub>2</sub> S (g)	227	7.20	7.37	189.0	190.0
XXI.	C <sub>18</sub> H <sub>10</sub> O <sub>7</sub> N <sub>2</sub> S (h)	255 (d)	8.25	8.80	—	—

(a) S found : 9.40 ; requires 9.10%

(b) S 11.20 11.45

(c) S 12.01 12.33 ; NH<sub>2</sub> found : 0.983 ; requires 1.0

(e) S 15.50 15.84 ; " 0.999 1.0

(f) S 8.50 8.75 ; " 0.940 1.0

(g) S 8.20 8.43 ; " " 0.921 1.0

(h) S 9.20 9.47 ; " " 0.921 1.0

(d) denotes decomposed.

STUDIES IN SULPHANILAMIDES. PART XIV. SOME NEW  
N<sup>4</sup>-HETEROCYCLIC ACYL-SULPHANILAMIDES\*

BY B. C. JAIN, B. H. IYER AND P. C. GUHA

Fourteen N<sup>4</sup>-heterocyclic acyl-sulphanilamides are described.

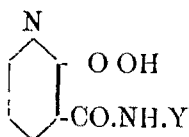
Although according to Fourné *et al.* (*Compt. rend. soc. Biol.*, 1936, 122, 258) the therapeutic activity of sulphanilamide is greatly reduced by the introduction of an acyl group at N<sup>4</sup>-position, the fact that N<sup>4</sup>-substituted sulphanilamides like N<sup>4</sup>-furoyl sulphapyridine (Kolloff and Hunter, *J. Amer. Chem. Soc.*, 1940, 62, 1646), N<sup>4</sup>-nicotiny sulphanilamide (Daniels and Iwamoto, *ibid.*, 1940, 62, 741), N<sup>4</sup>-quinolyl sulphanilamide (Hykes *et al.*, *Compt. rend. soc. Biol.*, 1937, 126, 635) and N<sup>4</sup>-2-pyrrolidone-5'-carboxy-4-aminobenzene sulphanilamide (Gray *et al.*, *Biochem. J.*, 1937, 31, 724) have been reported to possess high therapeutic activity, would warrant further studies in this direction. It was therefore thought of interest to make a systematic study of the effect of heterocyclic diacyl substituents at the N<sup>4</sup>-position of the sulphanilamide molecule.

The present paper details the preparation and properties of fourteen N<sup>4</sup>-heterocyclic acyl-sulphanilamides obtained from the following heterocyclic acids, esters or anhydrides: (a) quinolinic acid (*cf.* Jain *et al.*, *J. Indian Chem. Soc. Ind. & News Ed.*, 1945, 8, 59), (b) diethyldihydrocollidine dicarboxylate, (c) collidine dicarboxylic acid, (d) chelidamic acid, (e) furan-2 : 5-dicarboxylic acid, (f) diethyl 3 : 4-dihydroxyfuran-2 : 5-dicarboxylate (Guha and Iyer, *J. Indian Inst. Sci.*, 1938, 21A, 115), (g) diethyl furo-3 : 4-*p*-2 : 5-dicarboxylate, (h) cantharidin, (i) diethyl 3 : 4-dihydroxythiophen-2 : 5-dicarboxylate, (j) diethyl thieno-3 : 4-*p*-dioxan-2 : 5-dicarboxylate, and (k) diethyl diacetosuccinate.

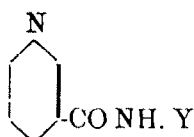
\* *cf.* Jain *et al.*, *Science & Culture*, 1945-46, 11, 270.

Quinolinic anhydride reacts with sulphanilamide to give pyridine-2-carboxy-3-carbo-N<sup>4</sup>-sulphanilamide (I) which, when heated at 200-210°, eliminates CO<sub>2</sub> giving N<sup>4</sup>-nicotiny sulphanilamide (II) showing that the COOH- in the 2 position of compound (I) is free.

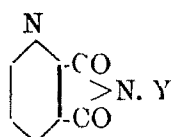
In all the formulae in this paper, Y stands for  $C_6H_4SO_2.NH_2$ .



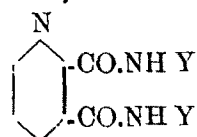
(I)



(II)



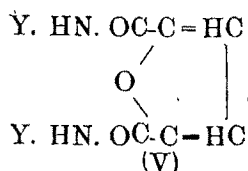
(III)



(IV)

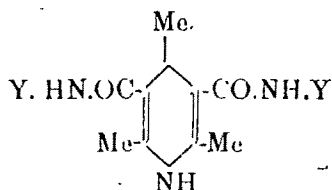
When (I) is treated with thionyl chloride, it gives pyridine-2 : 3-dicarbo- $N^4$ -monosulphanilamide (III) instead of the acid chloride of (I) apparently through the formation of the acid chloride and the simultaneous elimination of HCl.

Fusion of quinolinyll chloride and the dichloride of 2 : 5-furan dicarboxylic acid with sulphanilamide gives pyridine-2 : 3-dicarbo- $N^4$ -disulphanilamide (IV) and furan-2 : 5-dicarbo- $N^4$ -disulphanilamide (V), respectively.

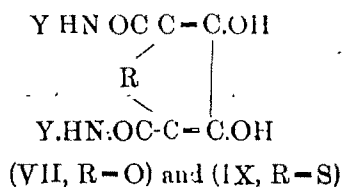


(V)

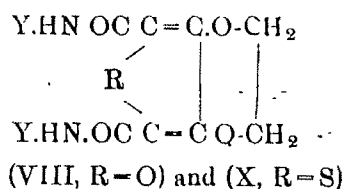
Fusion of the esters (b), (f), (g), (i) and (j) with sulphanilamide under vacuum leads to the formation of dihydrocollidine-3 : 5-dicarbo- $N^4$ -disulphanilamide (VI), 3 : 4-dihydroxyfuran-2 : 5-dicarbo- $N^4$ -disulphanilamide (VII), 3 : 4-ethylenedioxyfuran-2 : 5-dicarbo- $N^4$ -disulphanilamide (VIII), 3 : 4-dihydroxythieno-2 : 5-dicarbo- $N^4$ -disulphanilamide (IX) and 3 : 4-ethylenedioxythieno-2 : 5-dicarbo- $N^4$ -disulphanilamide (X), respectively.



(VI)

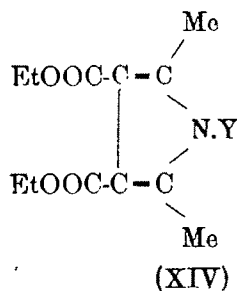
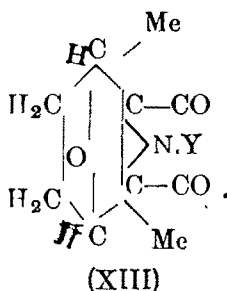
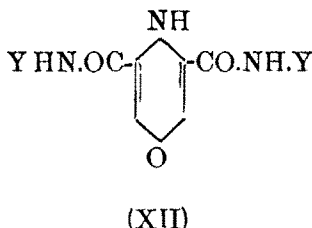
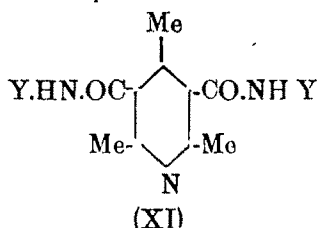


(VII, R=O) and (IX, R=S)



(VIII, R=O) and (X, R=S)

Fusion of (c), (d) and (h) gives collidine-3 : 5-dicarbo- $N^4$ -disulphanilamide (XI), pyridon-2 : 6-dicarbo- $N^4$ -disulphanilamide (XII) and 1 : 4-endoxy-*cyclohexane*-2 : 3-dimethyl-2 : 3-dicarbo- $N^4$ -sulphanilamide (XIII), respectively.



Action of (k) on sulphanilamide in acetic acid gives 2 : 5-dimethyl-3 : 4-dicarbethoxypyrrole- $N$ -*p*-benzene sulphonamide (XIV). Further condensation of sulphanilamide with the two carbethoxy groups of (XIV) could not be effected under any condition. Similarly diethyl 2 : 3-dimethylpyrrole-2 : 4-dicarboxylate and diethyl 2 : 4-dimethylpyrrole-3 : 5-dicarboxylate did not also react with sulphanilamide indicating the inert nature of the carbethoxy groups.

## E X P E R I M E N T A L

All the compounds and their analytical data are tabulated below. Most of them being insoluble in common organic solvent were purified by dissolution in 10% alkali and precipitation with dilute hydrochloric acid.

Compounds (I) and (XIV) were prepared by refluxing the solution of the reactants in alcohol and glacial acetic acid respectively, while (II), (III), (IV), (VII), (VIII) and (XIII) were prepared by heating the reactants at suitable temperatures at ordinary pressure; (V), (IX), (X), (XI) and (XII) were prepared by heating the components at reduced pressure. Two typical experiments are detailed below.

*Pyridine*-2 : 3-dicarbo- $N^4$ -disulphanilamide (IV).— To sulphanilamide (3.5 g.), taken in a flask fitted with an air condenser, protected by a calcium chloride tube, quinolinyl chloride (2.5 g.) was added dropwise with shaking and cooling. After 1 hour's keeping at room temperature, it was heated on a water-bath for 1 hour until evolution of HCl ceased. Dry benzene (15 c. c.) was added and after refluxing for 5 minutes, it was filtered hot and the product purified, m. p. 293° (decomp.), yield 2.4 g.

*Dihydrocollidine-3 : 5-dicarbo-N<sup>4</sup>-disulphanilamide* (V).— Sulphanilamide (3.42 g.) and diethyl dihydrocollidine dicarboxylate (2.67 g.) were heated in an oil-bath under reduced pressure (200 mm.) at 150-160° for 2 hours, and then at 200-210° for 1 hour. At the end of the period the molten mass resolidified indicating the completion of the reaction. This was purified as usual, yield 2.6 g., m. p. 285° (decomp.).

TABLE I

No.	Formula.	M.p. (a)	%Nitrogen		%Sulphur	
			Found.	Calc.	Found.	Calc.
I.	C <sub>13</sub> H <sub>11</sub> O <sub>3</sub> N <sub>3</sub> S (c)	210° (b)	13.19	13.08	10.27	9.97
II.	C <sub>12</sub> H <sub>11</sub> O <sub>3</sub> N <sub>2</sub> S	257	11.40	11.55	—	—
III.	C <sub>13</sub> H <sub>9</sub> O <sub>4</sub> N <sub>3</sub> S	311	13.80	13.86	10.90	10.56
IV.	C <sub>19</sub> H <sub>17</sub> O <sub>6</sub> N <sub>5</sub> S <sub>2</sub>	293	14.54	14.73	13.01	13.47
V.	C <sub>22</sub> H <sub>24</sub> O <sub>6</sub> N <sub>5</sub> S <sub>2</sub>	285	13.42	13.49	11.93	12.33
VI.	C <sub>22</sub> H <sub>22</sub> O <sub>6</sub> N <sub>5</sub> S <sub>2</sub>	280	13.40	13.54	12.20	12.37
VII.	C <sub>19</sub> H <sub>17</sub> O <sub>7</sub> N <sub>5</sub> S <sub>2</sub>	322	14.13	14.26	12.82	13.03
VIII.	C <sub>19</sub> H <sub>15</sub> O <sub>7</sub> N <sub>4</sub> S <sub>2</sub>	255	12.00	12.07	13.43	13.80
IX.	C <sub>18</sub> H <sub>15</sub> O <sub>6</sub> N <sub>4</sub> S <sub>2</sub>	260	11.44	11.30	13.25	12.90
X.	C <sub>20</sub> H <sub>15</sub> O <sub>6</sub> N <sub>4</sub> S <sub>2</sub>	275	10.84	10.72	12.01	12.26
XI.	C <sub>18</sub> H <sub>15</sub> O <sub>8</sub> N <sub>4</sub> S <sub>2</sub>	(d)	10.84	10.94	13.10	13.75
XII.	C <sub>20</sub> H <sub>15</sub> O <sub>8</sub> N <sub>4</sub> S <sub>2</sub>	(d)	10.51	10.40	13.50	13.84
XIII.	C <sub>16</sub> H <sub>15</sub> O <sub>5</sub> N <sub>3</sub> S	234	8.24	8.00	9.40	9.14
XIV.	C <sub>16</sub> H <sub>23</sub> O <sub>5</sub> N <sub>3</sub> S	204	7.20	7.10	8.40	8.12

(a) Most of the compounds melted with decomposition.

(b) Solidified when kept at 210° for some time and remelted at 257-60°.

(c) Equivalent : Found, 317.4; calc., 321.

(d) Decomposed.

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# STUDY OF THE CONDITIONS OF PRECIPITATION OF CUPRIC HYDROXIDE FROM CUPRIC SALTS BY SOLUBLE HYDROXIDES. PART I. REACTION BETWEEN SOLUTIONS OF CUPRIC SULPHATE AND SODIUM HYDROXIDE

BY ARUN K. DEY AND SATYESHWAR GHOSH

Precipitation of cupric hydroxide from a solution of cupric sulphate by the addition of sodium hydroxide has been studied. The colour of the precipitate is found to vary remarkably with the amounts of alkali added and also with time. The amount of sodium hydroxide needed for the complete precipitation of copper in solution is about 10% less than the equivalent quantity and this behaviour can be explained on the basis of hydrolytic adsorption of the  $\text{SO}_4^{2-}$  radical by cupric hydroxide when the medium is not sufficiently alkaline. It is further concluded that the adsorption of sulphate diminishes with the increase in the alkalinity of the medium, because of the amphoteric character of cupric hydroxide. This happens at lower temperatures, for example at  $30^\circ$ , but at  $50^\circ$  and  $80^\circ$ , the adsorption of sulphate becomes negligible and complete precipitation occurs practically with equivalent quantities.

The colour and properties of cupric hydroxide precipitated by alkali solutions vary according to the conditions of precipitation. The amount of alkali required for complete removal of copper from the solution of cupric sulphate is also smaller than the equivalent amount. This paper records some of the results on the nature of such hydrated cupric oxide.

## EXPERIMENTAL

The concentration of the cupric sulphate (AnalaR) solution used was  $0.4805M$  and that of sodium hydroxide,  $1.9665M$ . Cu was estimated both gravimetrically and volumetrically; sulphate was estimated as  $\text{BaSO}_4$ .

From 10 c. c. of the cupric sulphate solution, the hydroxide was precipitated by different quantities of alkali and the colour of the precipitates obtained varied from light blue to green and finally with increasing amounts of alkali, and in general, showed a tendency to darken with time. It was further noted that copper was completely precipitated when 1.759 equiv. of alkali were added, but the filtrate remained neutral even with 1.821 equivs. of alkali, and with further increase of alkali, the filtrate too became alkaline.

Now, to 10 c. c. of the cupric sulphate solution, taken in graduated flasks, were added different volumes of alkali solution, measured from a microburette, and the total volumes raised to 100 c. c. The flasks were left overnight, and alkali was estimated in the supernatant liquids. The compositions of the precipitates were calculated on the basis, that the amount of alkali used up completely converted the cupric sulphate into the hydroxide. The excess of the cupric sulphate was considered to be associated with the hydrated oxide as adsorption complexes or basic salts. The precipitation was effected at  $30^\circ$ , and the alkali estimated.

Finally the flasks together with the contents were kept in the thermostats maintained at 50° and 80° successively, and the amounts of alkali unused were determined in each case. The results are recorded below.

TABLE I

Amount of cupric sulphate = 4.805 mg. moles in 100 c. c. of the mixture.

Alkali added (mg. <i>M</i> )	Temperature = 80°.		Temperature = 50°.		Temperature = 80°.	
	Alkali used up (mg. <i>M</i> )	Composition of the precipitate.	Alkali used up (mg. <i>M</i> )	Composition of the precipitate.	Alkali used up (mg. <i>M</i> )	Composition of the precipitate
9.8325	9.8325	CuO.002(OH)	9.8125	CuO.0.003(OH)	9.8125	CuO.0.003(OH)
9.6859	9.4489	59CuO.SO <sub>4</sub>	9.5859	50CuO.SO <sub>4</sub>	9.5859	50CuO.SO <sub>4</sub>
9.4392	9.4092	47CuO.SO <sub>4</sub>	9.4392	—	9.4392	—
9.2426	9.2246	24CuO.SO <sub>4</sub>	9.2426	—	9.2426	—
9.0459	9.0359	16CuO.SO <sub>4</sub>	9.0459	—	9.0459	—
8.8493	8.8453	12CuO.SO <sub>4</sub>	8.8493	—	8.8493	—
8.6526	8.6526	9.6CuO.SO <sub>4</sub>	8.6526	—	8.6526	—
8.4560	8.4560	7.3CuO.SO <sub>4</sub>	8.4560	—	8.4560	—

With lower amounts of alkali, some copper was found to remain unprecipitated as shown by the blue colour of the supernatant liquid.

In view of the wide variations in the nature and the compositions of the precipitates, they were kept in contact with a normal solution of ammonia; the cupric oxides obtained with smaller amounts of alkali readily dissolved in ammonia, whilst those obtained with excess of alkali did not dissolve at all.

In another set of experiments, the hydrated oxide was precipitated with different quantities of alkali solution, the total volume of the heterogeneous mixture was raised to 100 c. c. and the precipitate allowed to settle for 24 hours at 30°. The amount of sulphate in the supernatant liquid was estimated as barium sulphate. Thus the amount of sulphate adsorbed was known. The results are recorded below.

TABLE II

Temperature = 30°.

Cupric sulphate taken = 4.805 mg. *M* in 100 c. c. of the mixture.

Amount of alkali added.	Sulphate in the supernatant liquid.	Sulphate associated with the precipitate.
9.4392 mg. <i>M</i>	4.480 mg. <i>M</i>	0.325 mg. <i>M</i>
8.8493	4.120	0.685
8.2598	3.886	0.969
7.8660	3.752	1.053

It was thought necessary to estimate the amount of sulphate retained by the hydrated cupric oxide even after thorough washing. The precipitates obtained after addition of alkali were washed till the filtrates were free from sulphate, and dissolved in Merck's pure hydrochloric acid, sulphate precipitated as barium sulphate, and estimated. The results are given below.

TABLE III

Cupric sulphate taken = 4.805 mg. *M* in 100 c. c. of the mixture.  
Temperature = 30°.

Amount of alkali added	Sulphate associated with the precipitate.	Composition of the precipitate.
9.8325 mg <i>M</i>	Nil	CuO
9.4392	0.1530 mg <i>M</i>	31.4CuO,SO <sub>4</sub>
8.8493	0.4120	11.7CuO,SO <sub>4</sub>
8.2593	0.6630	7.25CuO,SO <sub>4</sub>
7.8660	0.6230	7.43CuO,SO <sub>4</sub>

Tables II and III show that the amount of sulphate associated with hydrated cupric oxide, can only be washed partly and an appreciable quantity of sulphate is retained even after thorough washing.

## DISCUSSION

The results recorded in Table I show that 10 c. c. of a cupric sulphate solution containing 4.805 mg. atoms of copper in solution, which should require 9.610 mg. *M* of sodium hydroxide, could completely be precipitated by 9.610 mg. *M* of alkali at 30°. This can be explained, either from the view of precipitation of a basic salt of copper (*cf.* Pickering, *Chem. News*, 1883 47, 187; *J. Chem. Soc.*, 1883, 43, 337; Mehrotra and Dhar, *J. Phys. Chem.*, 1923, 33, 216; Britton, *J. Chem. Soc.*, 1925, 2799), or that of the adsorption of the sulphate ions from sodium sulphate (produced in the interaction) by the hydrated cupric oxide and the consequent production of OH<sup>-</sup> ions by hydrolytic adsorption, which precipitates the excess of copper left out in solution due to the addition of an insufficient quantity of alkali. In either case, however, the precipitate is likely to be contaminated by sulphate ions (Tables II and III). It is significant to observe that the amount of sulphate found associated with the precipitate is always greater than the difference in the amount of sodium hydroxide required for complete precipitation as cupric hydroxide and the amount that was actually added. Thus when sodium hydroxide added is less by 0.7601 mg. equiv. than the amount to complete the formation of cupric hydroxide, the amount of sulphate associated is found to be 1.37 mg. equivs. Moreover, from Table I the filtrate appears to remain sufficiently alkaline even when the precipitate has the composition of a basic salt, 12CuO, SO<sub>4</sub>. We have seen that well washed cupric hydroxide, obtained by the interaction of equivalent amounts of cupric salt and caustic soda solutions, when shaken with a solution of sodium sulphate liberates a detectable quantity of alkali. Thus the preferential adsorption of sulphate ions by hydrated cupric oxide can well explain the formation of an alkaline filtrate, even when sodium hydroxide added for precipitation is in smaller amounts than the equivalent quantity required for complete precipitation. This, therefore, leaves no doubt that sufficient amount of sulphate ions is adsorbed by cupric hydroxide and the following table confirms this observation even after thorough washing.



TABLE IV

Amount of cupric sulphate = 4.805 mg. moles in 100 c. c.

Amount of alkali added.	Amount of sulphate associated (in mg. <i>M</i> )		
	Total.	Unwashable.	Washable.
9.4892mg <i>M</i> .	0.325	0.153	0.172
8.8493	0.685	0.412	0.273
8.4560	0.969	0.663	0.306
7.8660	1.058	0.623	0.430

Our observations at 50° and 80° that for practically equivalent amount of the alkali added, the alkali remaining free remarkably decreases shows diminished preferential adsorption of sulphate which produces alkali.

It is of interest to note that the amount of sulphate found associated with cupric hydroxide goes on decreasing either as more and more of alkali is added or the temperature of the heterogeneous mixture is raised.

Dhar and Mehrotra (*loc. cit.*) have reported that in the estimation of copper as cupric oxide, the results are more near theoretical values, when larger amounts of alkali are employed for precipitation. This result is explainable from our viewpoint, that the adsorption of sulphate ion becomes negligible when cupric hydroxide is precipitated by a slight excess of alkali. The adsorption of alkali in this case is very small in comparison to the adsorption of sulphate ions. Further, the behaviour of cupric oxide to form cuprates is not remarkable, with the consequence, that the adsorption of OH<sup>-</sup> ions in presence of excess of alkali is loose and therefore washable.

The dissolution of the precipitates in ammonia has been qualitatively noted, and the results clearly indicate that cupric hydroxide, obtained in the presence of excess of alkali, has no tendency to form cuprammines, showing remarkable change in the property of cupric hydroxide precipitated with different amounts of alkali. This observation can be explained on the hypothesis that cupric oxide has an amphoteric character (Köhlshütter and Tüscher, *Z anorg. Chem.*, 1920, 111, 193; Weiser "The Hydrous Oxides", New York, 1926; p. 143), and that the acidic or the alkaline property will be guided by the alkaline or the acidic nature of the medium. It is well known that precipitates of basic character preferentially adsorb anions, while those of acid character, the cations; hence in presence of neutral or alkaline medium, when copper hydroxide is obtained, it is but likely to conclude that the acid character of copper hydroxide becomes predominant which deprives it of its capacity to adsorb an anion like sulphate. Hence in the formation of a complex ammine, where cupric hydroxide is likely to form a co-ordination compound with ammonia, this tendency will be more pronounced when the precipitate has neither acidic nor alkaline properties. More work, however, is necessary to confirm the view developed above, and further experimental work in this direction is in progress in this laboratory.

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## CONDENSATION OF ALDEHYDES WITH AMIDES. PART XIII. OF DIHYDROCINNAMALDEHYDE

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Condensation of dihydrocinnamaldehyde with some amides has been described. Formamide does not appear to condense at all; the others give a *bisamide* product. The presence of pyridine is not helpful; occasionally it gives resin and diminishes the yield. The yields are a little smaller than those obtained from cinnamaldehyde, the highest here did not exceed 42%.

In the present paper are studied the condensations of dihydrocinnamaldehyde with a few amides. These present some contrasts with those obtained from cinnamaldehyde. The products in both the cases are the *bisamides*, which resemble very greatly the other *bisamides* already obtained in this laboratory from other aldehydes. The yields in the present case do not exceed 40%, whereas the highest yields obtained in the cinnamaldehyde-amide condensations are generally higher, the highest reaching 56%.

The influence of a trace of piperidine, which usually favours the cinnamaldehyde-amide condensation (Mehra and Pandya, *Proc. Ind. Acad. Sci.*, 1938, 7A, 376), has been found to reduce the yield in the dihydrocinnamaldehyde-amide condensations (*vide* experimental). Temperatures higher than that of water-bath appeared favourable in both.

As in the case of several other aldehydes examined, formamide does not seem to condense at all with dihydrocinnamaldehyde under all the conditions tried, and with certain difficulty with cinnamaldehyde giving as a product what looks like a polymer (*unpublished work* by Mehra and Krishna Kumar Baslas). Table II at the end will make the comparison and the contrast clear.

### EXPERIMENTAL

*Condensation with Acetamide.*—(i). Dihydrocinnamaldehyde (1.34 g.) and acetamide (1.18 g.) (1 : 2 mol.) were heated in a flask (air-condenser) on a water-bath (98-99°) for 6 hours. After 2 hours the reactants changed into a reddish yellow solution. The flask was cooled overnight; the contents had turned into a brownish white solid next morning. The flask was again heated for 3 hours more; on cooling, the contents solidified again. They were washed repeatedly with water first and then with ether, till milk-white needle-shaped crystals were left behind

melting at 193°. On repeated recrystallisations (alcohol and water), the melting point rose to 206-207°.

(ii). The experiment was repeated with a little pyridine (1 : 1 : 0.15 mol.), the heating being carried on for 11 hours. The same product in a slightly smaller amount was obtained (yield, Table I). (The mixed melting point was 207°).

(iii). Instead of a water-bath, an oil-bath (120-125°) was used without any pyridine. The same product in a somewhat greater yield (more than double) came out (Table I).

The condensation product is insoluble in water, ether, benzene, acetone, chloroform; soluble in hot alcohol from which it is precipitated by addition of water. The pure product does not decolourise bromine or Baeyer's reagent in the cold, suggesting absence of unsaturation. Also it gave no colour with concentrated sulphuric acid. (The crude product, however, gave all the three tests, suggesting presence of a small amount of the mono-product which was unsaturated.) [Found : N, 12.38.  $C_{13}H_{13}O_2N_2$  (dihydrocinnamylidene-*bi*acetamide) requires N, 11.98 per cent : the mono-amide requires N, 8.4 per cent). On this basis the yields in the three experiments were 10.2%, 9.35% and 25.5% respectively.

*Condensation with Benzamide.*—(i). The aldehyde (1.34 g.) and benzamide (2.42 g.) in 1 : 2 mol. were heated in the same way on a water-bath. The mixture became a homogeneous liquid after 1 hour, and began to solidify after 2 hours; the total heating was for 8 hours. The product was taken out as before; it was fairly pure, as in the crude state it melted at 128°, but on recrystallisation m.p. rose up to 130° and was identical with benzamide itself.

(ii). When heated with 0.15 mol. of pyridine in the same way, the same result (unchanged benzamide) was obtained.

(iii). The aldehyde and the amide were heated alone at 140-150° (*c.f.* Mehra and Pandya, *Proc. Ind. Acad. Sci.*, 1939, 9A, 508). The mixture became a homogeneous liquid in a few minutes, but they soon solidified again. The heating was continued for 2½ hours. Next morning the hard mass was taken out, crushed and washed with hot water, filtered and washed with ether. The crude product, m.p. 230°, on recrystallisation from hot alcohol melted at 244-45° (m.p. 244-45°, Mehra and Pandya, *loc. cit.*). The yield was 1.41 g.

Its solubility was less than that of the *bi*-acetamide, as it was soluble only in hot alcohol or hot acetone. Its other properties are the same as already described, except that it gave a pinkish colour with concentrated sulphuric acid. [Found : N, 8.3.  $C_{23}H_{22}O_2N_2$  (dihydrocinnamylidene-*bi*benzamide) requires N, 7.82 per cent].

*Condensation with Propionamide.*—(i). Dihydrocinnamaldehyde (1.34 g.) and propionamide (1.44 g.) were heated on a water-bath as usual; after 1½ hours a dark, brown coloured solution was formed. Even after 6 hours' heating the contents did not solidify. On cooling and keeping it overnight,

the contents became a black-brown semi-solid. After two more hours' heating and cooling, the reacting mass solidified. The usual treatment gave a white mass melting (crude) at  $188^{\circ}$ . After several recrystallisations (dilute alcohol), the m.p. became constant at  $198-99^{\circ}$ , yield 0.3 g. (or 11.6% of theory).

(ii). Heated with a trace of pyridine as before for 11 hours even, the mass was found to become solid only after cooling. The same product was obtained in a slightly smaller yield, 0.25 g (9.6%).

(iii). The aldehyde and the amide were heated alone at  $115-120^{\circ}$  for 8 hours. The same product came out, the yield 0.75 g. (29% of theory).

(iv). A higher temperature ( $125-130^{\circ}$ ) did not increase the yield, but yielded a resinous mass from which only 0.32 g could be recovered. Thus  $115-120^{\circ}$  was found the optimum temperature.

The solubilities and reactions with bromine water and Baeyer's reagent were as before. A yellow colour was obtained with concentrated sulphuric acid. [Found: N, 11.1.  $C_{18}H_{22}O_2N_2$  (dihydrocinnamylidene-*bis*propionamide) requires N, 10.64 per cent].

*Condensation with n-Butyramide.*—The two were heated in molecular proportions (1 : 2) on a water-bath for 7 hours, cooled and kept overnight, when a brownish yellow solid was obtained. As some of the amide had volatilised away into the neck of the flask, it was washed in with a little of absolute alcohol and the flask was heated for another 6 hours (13 hours in all). A solid was found the next morning from which a white crystalline mass, m.p.  $140-41^{\circ}$ , was extracted by the usual method. Recrystallisations (dilute alcohol) raised the melting point to  $168-69^{\circ}$ . The yield was 0.32 g. (21.5% of theory).

It is soluble in dilute hot alcohol, and hot benzene; it does not react with bromine water, Baeyer's reagent or strong sulphuric acid. (Found N, 9.22. Dihydrocinnamylidene-*bis-n*-butyramide,  $C_{17}H_{26}O_2N_2$  requires N, 9.65 per cent).

*Condensation with n-Heptamide.*—(i). Heating the two alone on a water-bath, solidification was found to start in 4 hours. The total heating was for 7 hours; the crude product extracted therefrom melted at  $125^{\circ}$ . To a hot alcoholic solution cold distilled water was added when milky white flakes appeared; the final m.p.  $128-29^{\circ}$ , yield 0.81 g. (or 40% of theory).

(ii). Heating in an oil-bath ( $105-110^{\circ}$ ) for 6 hours only slightly increased the yield (to 0.84 g., 42%). Its properties and reactions were the same as recorded for the *bis*butyramide (Found: N 7.9. Dihydrocinnamylidene-*bis-n*-heptamide,  $C_{23}H_{38}O_2N_2$  requires N, 7.4 per cent).

*Condensation with Formamide*—This did not seem to take place, although several different experiments were tried using various temperatures and heating periods, and using pyridine, alcohol, hydrochloric acid and no condensing reagent.

TABLE I

Amide.	Condensing agent.	Heating period.		Yield.
Formamide	Several & none	100° to 170° ; several hours		0
Acetamide	None	98-99°	9 hrs.	10.2%
"	Pyridine	"	11	9.35
"	None	120-125°	6	25.5
Propionamide	"	98-99°	8	11.6
"	Pyridine	"	11	9.6
"	None	110-120°	8	29
"	"	125-130°	8	12.1
<i>n</i> -Butyramide	"	98-99°	13	21.5
<i>n</i> -Heptamide	"	"	7	40
"	"	105-110°	6	42
Benzamide	"	98-99°	8	0
"	Pyridine	"	8	0
"	None	140-150°	25	40

TABLE II

*Maximum yields from cinnamaldehyde and dihydrocinnamaldehyde.*

Amide.	Cinnamaldehyde.	Dihydrocinnamaldehyde.
1. Formamide	A polyper ; yield good	0
2. Acetamide	51%	25.5%
3. Propionamide	48	29
4. <i>n</i> -Butyramide	(Not done)	40
5. <i>n</i> -Heptamide	42%	42
6. Benzamide	55	40

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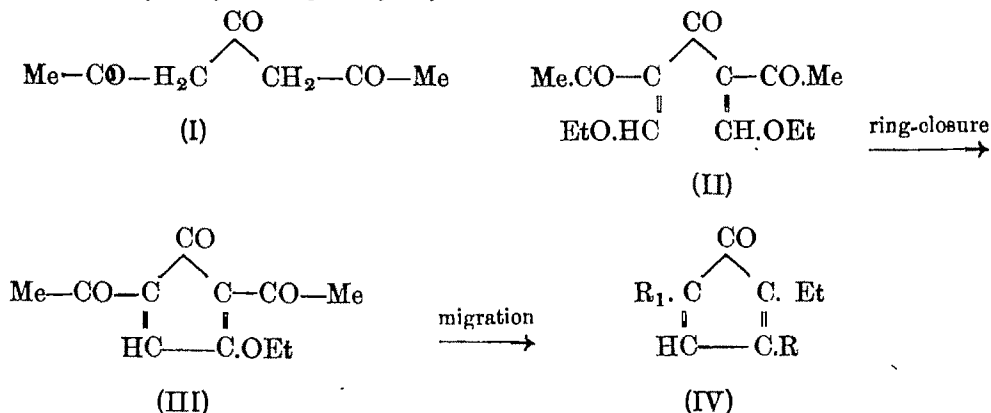
*Received November 19, 1948.*

# PYRONES AND RELATED COMPOUNDS. PART VII. ACTION OF ETHYL *o*-FORMATE ON DIACETYLACETONE

BY R. KAUSHAL

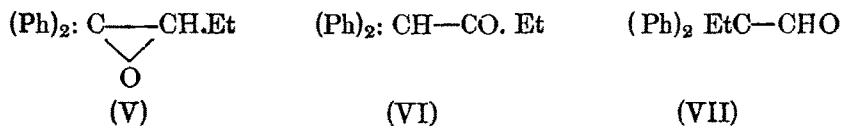
Ethyl-*o*-formate reacts with the two methylene groups of diacetylacetone to form a diethoxymethylene compound which immediately undergoes ring-closure and transforms to form 2-ethyl-3-acetoxy-5-acetyl- $\Delta^2$  3.4.5-cyclopentenone which undergoes hydrolysis with a concentrated solution of potassium hydroxide and on acidifying gives 2-ethyl-3-hydroxy- $\Delta^2$  3.4.5-cyclopentenone. It forms an acetyl derivative.

Diacetylacetone has the structure (I) and contains in its molecule two reactive methylene groups. It could not be condensed with sodium and formic ester for the simple reason that it forms its own sodium derivative which inhibits further action. Further, it undergoes self-condensation in presence of basic condensing agents like piperidine (Kaushal, *J. Indian Chem. Soc.*, 1946, 23, 17) to form dihydroxydimethylacetylnaphthalene.



Diacetylacetone on heating with *ortho*formic ester in presence of acetic anhydride gives a crystalline solid (m.p. 106°). The analysis of the compound corresponds to the formula  $\text{C}_{11}\text{H}_{12}\text{O}_4$ , and on treatment with strong potash solution on warming it yields a solid potassium derivative which, in turn on acidifying, affords a product (m.p. 177°) of the formula  $\text{C}_7\text{H}_8\text{O}_2$  which with acetic anhydride or acetyl chloride gives a monoacetate of the composition  $\text{C}_9\text{H}_{10}\text{O}_3$  (m.p. 135°). These reactions could only be explained in the following manner.

At first by the reaction of *ortho*formic ester on the reactive methylene groups of diacetylacetone (I), the diethoxymethylene diacetylacetone (II) is formed which could not be isolated as it readily undergoes ring-closure to form the compound (III). The latter undergoes transformation to give (IV,  $\text{C}_{11}\text{H}_{12}\text{O}_4$ ;  $\text{R} = \text{CH}_3\text{CO}_2$ ;  $\text{R}_1 = \text{CH}_3.\text{CO}$ ) in which both the ethyl and acetyl groups migrating and exchanging places. This is somewhat peculiar transformation which has been noticed in this case. There are reasons to believe that the ethyl group migrates as Levy and Langrave (*Compt. rend.*, 1925, 180, 1032) working on the rearrangement of asymmetric glycols have shown that the ethyl group is capable of migration. Thus 1:1-diphenylbutane oxide (V) gives on isomerisation 1:1-diphenylbutanone (VI) and 1:1-diphenylethylacetaldehyde (VII).



The compound (IV,  $R_1 = \text{CH}_3\text{CO}$  ;  $R = \text{CH}_3\text{CO}_2$ ) on treatment with concentrated solution of KOH is hydrolysed somewhat like acetylacetone itself and the two acetyl groups are removed resulting in the formation of the potassium derivative (IV,  $R_1 = \text{CH}_3\text{CO}$  ;  $R = \text{OK}$ ) which when decomposed with acids gives the cyclopentenone derivative (IV,  $R_1 = \text{H}$  ;  $R = \text{OH}$ ), the hydroxyl of which readily reacts with acetic anhydride to form the monoacetyl derivative (IV,  $R_1 = \text{H}$  ;  $R = \text{CH}_3\text{CO}_2$ ).

### EXPERIMENTAL

*Condensation of Diacetylacetone with orthoFormic Ester : Formation of* (IV,  $R = \text{CH}_3\text{CO}_2$  ;  $R_1 = \text{CH}_3\text{CO}$ ).—Diacetylacetone (5.5 g.), orthoformic ester (12 g.) and acetic anhydride (25 drops) were refluxed with an air condenser on a sand-bath for 4 hours when a portion of the reaction mixture solidified on a watchglass. On cooling some solid separated which was filtered and the filtrate mixed with an equal volume of water and allowed to crystallise. By the next day star-shaped crystalline needles separated which were filtered and the filtrate gave a second crop. This was somewhat gummy and therefore purified by rubbing with alcohol ; total yield 2 g. It was crystallised from benzene and petrol as long, thin needles, m.p.  $106^\circ$ . (Found : C, 63.5, 63.8 ; H, 5.3, 6.0.  $\text{C}_{11}\text{H}_{12}\text{O}_4$  requires C, 63.5 ; H, 5.8 per cent).

If however, acetic anhydride is used in molecular proportion, only a gum results from which no definite product could be isolated.

*Action of concentrated solution of KOH on* (IV,  $R_1 = \text{CH}_3\text{CO}$  ;  $R = \text{CH}_3\text{CO}_2$ ) : *Formation of* (IV,  $R = \text{OH}$  ;  $R_1 = \text{H}$ ).—The compound (IV,  $R = \text{CH}_3\text{CO}_2$  ;  $R_1 = \text{CH}_3\text{CO}$ ) (2g.) was treated with 50% KOH solution when a yellow potassium derivative was formed on warming. It was filtered and washed with a little water in which the potassium derivative was sparingly soluble. The potassium derivative was suspended in water and decomposed with hydrochloric acid when it gave the compound (IV,  $R = \text{OH}$  ;  $R_1 = \text{H}$ ) as a canary yellow solid which was filtered, washed and dried, m.p.  $177^\circ$ . The aqueous filtrate from the potassium derivative on acidifying with hydrochloric acid also gave a little more of the same solid but this was impure and gummy ; total yield 15 g. On crystallisation from alcohol it melted at  $177^\circ$ . (Found : C, 67.8 ; H, 5.8.  $\text{C}_7\text{H}_8\text{O}_2$  requires C, 67.7 ; H, 6.4 per cent).

This appears to form phenylhydrazone in glacial acetic acid solution.

*The acetyl derivative* (IV,  $R = \text{CH}_3\text{CO}_2$  ;  $R_1 = \text{H}$ ) was obtained in the usual manner by boiling the compound (m.p.  $177^\circ$ ) with acetic anhydride or acetyl chloride and a drop of sulphuric acid. On cooling and pouring the reaction product in water it came out as almost colourless plates having shining lustre, m.p.  $135^\circ$ . (Found : C, 65.5 ; H, 6.3.  $\text{C}_9\text{H}_{10}\text{O}_3$  requires C, 65.1 ; H, 6.1 per cent).

The author is grateful to Prof. S. S. Deshapande for his very kind interest in the work and to the Holkar Government for the generous facilities for work.

# STUDIES IN SULPHONES. PART I. SCHIFF'S BASES OF 4'-NITRO-4'-AMINODIPHENYLSULPHONE AND THEIR REDUCTION PRODUCTS \*

BY B. C. JAIN, P. MIRCHANDANI, B. H. IYER AND P. C. GUHA

Twenty-four Schiff's bases of 4-nitro-4'-amino-, and 4:4'-diamino-diphenylsulphones are described.

In the development of antibacterial chemotherapy during the past decade much attention has been paid to the study of substituted sulphanilamides but no systematic attempts have been made to develop the drugs of the sulphone type. The discovery of the high antistreptococcal activity, though accompanied with high toxicity, of 4:4'-diaminodiphenylsulphone (Buttle *et al.*, *Lancet*, 1937, **i**, 1331) and its possible use in the treatment of tuberculosis and leprosy (Raiziss *et al.*, *J. Amer. Chem. Soc.*, 1939, **61**, 2763; Smith *et al.*, *J. Pharm. Expt. Ther.*, 1942, **74**, 163; Roblin *et al.*, *J. Amer. Chem. Soc.*, 1941, **63**, 1930) led to the synthesis of Promin (*cf.* Jain *et al.*, *Science & Culture*, 1945-46, **11**, 568), Diasone (Baner, *J. Amer. Chem. Soc.*, 1939, **61**, 617) and Promizole (Bambas, *ibid.*, 1945, **67**, 668).

Analogous to the Schiff's bases of sulphanilamide (Goissedet *et al.*, *Compt. rend. soc. Biol.*, 1936, **121**, 1082; Gray *et al.*, *Biochem. J.*, 1937, **31**, 724) which have been shown to possess good therapeutic property with the added advantage of low toxicity, it was thought of interest to make a systematic study of the Schiff's bases of 4-nitro-4'-amino- and 4:4'-diaminodiphenylsulphones in anticipation of their possessing low toxicity.

Condensation of 4-nitro-4' aminodiphenylsulphone with (i) benzaldehyde, (ii) *o*-methoxy-, (iii) *p*-methoxy-, (iv) *o*-hydroxy-, (v) *m*-nitro-, (vi) *p*-dimethyl-amino-, (vii) *p*-diethylamino-, (viii) 3:4-methylenedioxy-benzaldehydes, (ix) 3:4-methylenedioxy-6-nitrobenzaldehyde, (x) 2-hydroxynaphthaldehyde, (xi) cinnamic aldehyde and (xii) furfuraldehyde gave the twelve odd numbered nitro-Schiff's bases respectively, having the general formula (A) (vide Table I below).

Compounds (I), (III), (V), (VII), (XV) and (XIX) on reduction with sodium hydrosulphite gave (II), (IV), (VI), (VIII), (XVI) and (XX) respectively, of the general formula (B) (vide Table I). These six amino-Schiff's bases were also prepared by the action of the corresponding aldehydes on 4:4'-diaminodiphenylsulphone. The nitro-Schiff's bases (IX), (XI), (XIII), (XVII), (XXI) and (XXIII) decomposed on reduction into 4:4'-diaminodiphenylsulphone and the respective aldehyde; the corresponding even-numbered amino-Schiff's bases were, however, prepared from 4:4'-diaminodiphenylsulphone by the direct action of the respective aldehyde.

Except in the case of cinnamic aldehyde, which gave [XXII,  $(C_6H_5CH=CH-CH=N.C_6H_4)_2.SO_2$ ], in no other case could two molecules of the aldehyde be condensed with 4:4'-diaminodiphenylsulphone.

Buttle *et al.* (*Biochem. J.*, 1938, **32**, 1101) have prepared (II), (VI) (XII), (XVI) and (XXII) from 4:4'-diaminodiphenylsulphone and reported them to be less toxic than the parent sulphone.

## EXPERIMENTAL

All the compounds and their analytical data are tabulated below.

The odd-numbered nitro-Schiff's bases from 4-nitro-4'-aminodiphenylsulphone, with the exception of (IX), were prepared by the general procedure described for

\* Preliminary note published in *Science & Culture*, 1945-46, **11**, 567.



(I). Product (IX) was prepared either by the dry fusion of the reactants or by conducting the reaction in alcohol in the presence of zinc chloride.

Out of the twelve even-numbered amino-Schiff's bases (II), (IV), (VI), (VIII) (XVI) and (XX) were prepared by the general procedure described for (II) by the reduction of the corresponding nitro compound. The remaining amino-Schiff's bases were prepared by the condensation of 4: 4'-diaminodiphenylsulphone with the corresponding aldehyde either by fusion or in the presence of alcohol.

4-Nitro-4'-benzylideneaminodiphenylsulphone (I).—4-Nitro-4'-aminodiphenylsulphone (2.8 g) and benzaldehyde (1.5 g) in absolute alcohol (15 c.c.) were refluxed for 1 hour when the product separated. This was filtered out, washed with hot alcohol and crystallised from pyridine, m.p. 184°, yield 3.6 g.

4-Amino-4'-benzylideneaminodiphenylsulphone (II).—To a suspension of compound (I, 1 g) in alcohol (5 c.c.) boiling under reflux, sodium hydrosulphite (3 g) suspended in water (10 c.c.) was gradually added during 1 hour when a clear solution resulted. This was neutralised with 5% sodium hydroxide solution and the precipitated product was collected, washed with water and crystallised from dilute acetic acid, m.p. 231°, yield 0.6 g.

TABLE I

(A)  $\text{O}_2\text{N}-\langle \text{C}_6\text{H}_4 \rangle-\text{SO}_2-\langle \text{C}_6\text{H}_4 \rangle-\text{N}=\text{CH.R}$

(B)  $\text{H}_2\text{N}-\langle \text{C}_6\text{H}_4 \rangle-\text{SO}_2-\langle \text{C}_6\text{H}_4 \rangle-\text{N}=\text{CH.R}$

R stands for the  
respective aldehyde  
less -CHO.

No.	Formula of Schiff's base.	M.p.	%Nitrogen		%Sulphur	
			Found.	Calc.	Found.	Calc.
I.	$\text{C}_{16}\text{H}_{14}\text{O}_4\text{N}_2\text{S}$	184°	7.55	7.65	8.56	8.74
II.	$\text{C}_{16}\text{H}_{16}\text{O}_2\text{N}_2\text{S}$	231	8.14	8.88	—	—
III.	$\text{C}_{20}\text{H}_{16}\text{O}_5\text{N}_2\text{S}$	192	7.07	7.00	7.97	8.08
IV.	$\text{C}_{20}\text{H}_{16}\text{O}_3\text{N}_2\text{S}$	199	7.40	7.65	—	—
V.	$\text{C}_{20}\text{H}_{16}\text{O}_5\text{N}_2\text{S}$	203	6.94	7.00	—	—
VI.	$\text{C}_{20}\text{H}_{16}\text{O}_4\text{N}_2\text{S}$	227	7.78	7.65	—	—
VII.	$\text{C}_{19}\text{H}_{14}\text{O}_5\text{N}_2\text{S}$	226	7.42	7.83	—	—
VIII.	$\text{C}_{19}\text{H}_{16}\text{O}_3\text{N}_2\text{S}$	172	8.08	7.99	—	—
IX.	$\text{C}_{16}\text{H}_{16}\text{O}_6\text{N}_2\text{S}$	210	10.00	10.22	—	—
X.	$\text{C}_{19}\text{H}_{16}\text{O}_4\text{N}_2\text{S}$	243	11.10	11.03	—	—
XI.	$\text{C}_{21}\text{H}_{19}\text{O}_4\text{N}_2\text{S}$	122	10.13	10.27	7.74	7.82
XII.	$\text{C}_{21}\text{H}_{21}\text{O}_2\text{N}_2\text{S}$	249	11.05	11.10	—	—
XIII.	$\text{C}_{15}\text{H}_{23}\text{O}_4\text{N}_2\text{S}$	213	9.52	9.61	—	—
XIV.	$\text{C}_{23}\text{H}_{25}\text{O}_2\text{N}_2\text{S}$	222	10.49	10.32	—	—
XV.	$\text{C}_{20}\text{H}_{14}\text{O}_6\text{N}_2\text{S}$	216	6.77	6.83	7.99	7.80
XVI.	$\text{C}_{20}\text{H}_{16}\text{O}_4\text{N}_2\text{S}$	230	7.87	7.87	—	—
XVII.	$\text{C}_{20}\text{H}_{16}\text{O}_5\text{N}_2\text{S}$	240	9.35	9.23	7.19	7.03
XVIII.	$\text{C}_{20}\text{H}_{16}\text{O}_6\text{N}_2\text{S}$	241	10.10	9.98	—	—
XIX.	$\text{C}_{23}\text{H}_{16}\text{O}_5\text{N}_2\text{S}$	234	6.61	6.48	7.22	7.41
XX.	$\text{C}_{23}\text{H}_{18}\text{O}_3\text{N}_2\text{S}$	238	7.21	7.00	—	—
XXI.	$\text{C}_{21}\text{H}_{16}\text{O}_4\text{N}_2\text{S}$	194	7.03	7.14	—	—
XXII.	$\text{C}_{30}\text{H}_{44}\text{O}_2\text{N}_2\text{S}$	244	5.85	5.88	—	—
XXIII.	$\text{C}_{17}\text{H}_{12}\text{O}_5\text{N}_2\text{S}$	150	7.68	7.86	9.20	9.00
XXIV.	$\text{C}_{17}\text{H}_{14}\text{O}_5\text{N}_2\text{S}$	153	8.55	8.60	—	—

# STRUCTURE OF THE PERIODATES. PART III. MAGNETIC STUDY OF THE PARAMAGNETIC PERIODATES OF Cu, Ni, Ce AND Y

BY ROOP CHAND SAHNEY, S. L. AGGARWAL AND MAHAN SINGH

The magnetic susceptibilities of the periodates of Cu, Ni, Co, Ce and Y have been determined. From the comparison of  $\mu_B$  values of these ions with the theoretically calculated  $\mu_B$  values, these periodates have been shown to be simple salts of the periodic acids and not the complex salts.

In previous communications (*J. Indian Chem. Soc.*, 1945, 22, 158 ; 1946, 23, 177) the diamagnetic susceptibility values of the periodic acid and the periodates of Na, Ag, Hg, and La were reported and their structures discussed. We have now determined the magnetic susceptibilities of the periodates of Cu, Ni, Co, Ce and Y, all of which are paramagnetic. As already pointed out (*loc. cit.*), it is not always possible to assign any definite formulae to the periodates from analytical results. These paramagnetic periodates can be represented by the simple salt as well as complex salt formulae. The magnetic susceptibility values of these periodates will definitely indicate the nature of the salts formed i.e. simple or complex ; because in the latter case, large deviations between the experimental and theoretically calculated values will occur.

## EXPERIMENTAL

Pure AnalaR salts were used in the preparation of these periodates.

*Copper periodate* was prepared by the addition of  $\text{Na}_2\text{H}_3\text{IO}_6$  in dilute nitric acid to copper sulphate. (Found : Cu, 36.2 ; I, 36.3 ; O, 15.97.  $\text{Cu}_2\text{HIO}_6$  requires Cu, 36.20 ; I, 36.17 ; O, 15.95 per cent) according to decomposition  $4\text{Cu}_2\text{HIO}_6 \longrightarrow 8\text{CuO} + 2\text{I}_2 + 2\text{H}_2\text{O} + 7\text{O}_2$ .

*Cobalt periodate* was prepared by the action of  $\text{KIO}_4$  on  $\text{Co}(\text{NO}_3)_2$ . (Found : Co, 25.97 ; I, 28.1 ; O, 12.22.  $\text{Co}_4\text{I}_2\text{O}_{13} \cdot 12\text{H}_2\text{O}$  requires Co, 25.87 ; I, 27.8 ; O, 12.36 per cent) according to decomposition  $\text{Co}_4\text{I}_2\text{O}_{13} \cdot 12\text{H}_2\text{O} \longrightarrow 2\text{Co}_2\text{O}_3 + \text{I}_2 + 12\text{H}_2\text{O} + 7\text{O}$ .

*Nickel periodate* was prepared by the addition of  $\text{Na}_2\text{H}_3\text{IO}_6$  in dilute nitric acid to  $\text{NiSO}_4$ . [Found : Ni, 31.2 ; I, 28.23 ; O, 11.75.  $\text{Ni}_5(\text{IO}_6)_2 \cdot 13\text{H}_2\text{O}$

requires Ni, 31.67; I, 27.50; O, 12.12 per cent] according to decomposition  $\text{Ni}_5(\text{IO}_6)_2 \cdot 13\text{H}_2\text{O} \longrightarrow 5\text{NiO} + \text{I}_2 + 13\text{H}_2\text{O} + 7\text{O}$ .

*Yttrium periodate* was obtained as a white powder by adding  $\text{Na}_2\text{H}_3\text{IO}_6$  in dilute  $\text{HNO}_3$  to a solution of yttrium nitrate. (Found: Y, 24.15; I, 33.80; O, 15.2.  $\text{YIO}_5 \cdot 4\text{H}_2\text{O}$  requires Y, 24.12; I, 34.54; O, 15.3 per cent) according to decomposition  $\text{YIO}_5 \cdot 4\text{H}_2\text{O} \longrightarrow \text{Y}_2\text{O}_3 + \text{I}_2 + 3\text{H}_2\text{O} + 7\text{O}$ .

*Cerium periodate* was obtained as a yellow powder by the addition of  $\text{Na}_2\text{H}_3\text{IO}_6$  in dilute  $\text{HNO}_3$  to cerium nitrate solution. (Found: Ce, 33.4; I, 30.4; O, 11.50.  $\text{CeIO}_5 \cdot 4\text{H}_2\text{O}$  requires Ce, 33.40; I, 30.2; O, 11.45 per cent) according to decomposition  $2\text{CeIO}_5 \cdot 4\text{H}_2\text{O} \longrightarrow 2\text{CeO}_2 + \text{I}_2 + 8\text{H}_2\text{O} + \text{O}_2$ .

### Susceptibility Determinations

The susceptibilities were determined by the modified Guoy's balance (Nevgi, *Current Sci.*, 1945, 4, 403).  $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$ , freshly prepared and twice crystallised, was used as the reference substance. The working of the apparatus was checked by determining the magnetic susceptibilities of a number of specially purified paramagnetic salts. The experimental and reported values with % error for these are shown in Table I and susceptibility values for periodates in Table II.

TABLE I

No.	Substance.	Temp.	$\chi_M \times 10^{-6}$		
			Exp. (mean of 3 readings)	Reported.	% Error.
1.	$\text{Fe}(\text{SO}_4)(\text{NH}_4)_2\text{SO}_4 \cdot 7\text{H}_2\text{O}$	32.0°	31.2	31.1	0.30
2.	$\text{KCr}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$	33°	12.06	12.04	0.16
3.	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	32.5°	5.83	5.84	0.15

TABLE II

No.	Periodates.	Temp.	(mean of 3 readings)	$\chi_M \times 10^{-6}$
				per g. mo
1.	Copper periodate	32°	6.808	2387.85
2.	Nickel paraperiodate	32°	20.744	20193.24
3.	Cobalt dimesoperiodate	32°	23.67	21887.0
4.	Tetrahydrated cerium mesoperiodate	32°	5.143	2155.58
5.	Tetrahydrated yttrium mesoperiodate	32°	9.072	3337.86

## DISCUSSION

If it is assumed that the Curie's law is obeyed in the limited range of temperature used in the present investigation, the magnetic moment of the paramagnetic ions in the above periodates can be calculated in terms of Bohr magnetons according to the formula: effective magnetic moment in terms of Bohr magneton ( $\mu_B$ ) =  $2.84 \times \sqrt{\chi_M \times T}$ . The values of  $\mu_B$  in the above periodates are calculated below. It is necessary to account for the diamagnetic contributions of the periodate ion and water molecules in these salts. The diamagnetic values of periodate ions have been calculated as shown in a previous paper (*ibid.*, 1946, 23, 177). The diamagnetic contributions of the cores of the paramagnetic ions have not been considered as these are too small to affect the result.

*Calculations of Bohr magneton values for Co, Ni, Cu, Ce  
and Y in the periodates.*

1. Cu in $\text{Cu}_2\text{HIO}_6$ .	
$\chi_M$ (periodate)	= $2387.85 \times 10^{-6}$
$\chi_M$ ( $\text{IO}_6$ ion)	= $-52 \times 10^{-6}$
$\chi_M$ for 2 $\text{Cu}^{++}$ ions	= $2439.85 \times 10^{-6}$
.. for $\text{Cu}^{++}$ ion	= $1219.92 \times 10^{-6}$
$\mu_B$ for Cu	= $2.839 \sqrt{1219.9 \times 10^{-6} \times 805} = 17.8$
2. Ni ion in $\text{Ni}_2(\text{IO}_6)_2 \cdot 18\text{H}_2\text{O}$ .	
$\chi_M$ (periodate)	= $20193.24 \times 10^{-6}$
$2\chi_M$ ( $\text{IO}_6$ ion)	= $104.40 \times 10^{-6}$
$18\chi_M$ ( $\text{H}_2\text{O}$ )	= $-169.0 \times 10^{-6}$
$5\chi_M$ $\text{Ni}^{++}$	= $20.473.4 \times 10^{-6}$
$\chi_M$ $\text{Ni}^{++}$	= $4094.7 \times 10^{-6}$
$\mu_B$ $\text{Ni}^{++}$	= $2.839 \sqrt{4095 \times 10^{-6} \times 805} = 8.174$
3. Co ion in $\text{Co}_4\text{I}_2\text{O}_{18} \cdot 12\text{H}_2\text{O}$ .	
$\chi_M$ (periodate)	= $21629.6$
.. ( $\text{I}_2\text{O}_{18}$ ion)	= $-101.4 \times 10^{-6}$
.. ( $12\text{H}_2\text{O}$ ..)	= $-166.0 \times 10^{-6}$
$4\chi_M$ (cobalt ion)	= $2185.7 \times 10^{-6}$
$\chi_M$ (cobalt ion)	= $5471.7 \times 10^{-6}$
$\mu_B$ for cobalt ion	= $2.839 \sqrt{5471.7 \times 10^{-6} \times 805} = 9.67$

In the above formula for periodate, cobalt ion has been given the valency of three. Cobaltic ion has got  $\mu_B = 2$  (experimental), while the cobaltous ion has  $\mu_B = 4-5$  (experimental). In the above periodate  $\mu_B$  value for cobalt ion shows it to be in the cobaltous state. Therefore the formula of periodate is  $\text{Co}_4\text{H}_4\text{I}_2\text{O}_{18} \cdot 12\text{H}_2\text{O}$  and not  $\text{Co}_4\text{I}_2\text{O}_{18} \cdot 12\text{H}_2\text{O}$ .

$\mu_B$ for Y in $YIO_5 \cdot 4H_2O$			$\mu_B$ for $Ce^{++}$ in $CeIO_5 \cdot 4H_2O$		
$\chi_M$ (periodate)	=	$3337.86 \times 10^{-6}$	$\chi_M$ (periodate)	=	$2155.58 \times 10^{-6}$
" $IO_5$	=	$-51.95 \times 10^{-6}$	" $IO_5$	=	$-51.95 \times 10^{-6}$
$4\chi_M H_2O$	=	$-52.00 \times 10^{-6}$	$4\chi_M H_2O$	=	$-52.00 \times 10^{-6}$
$\chi_M$ (Y ion)	=	$3441.81 \times 10^{-6}$	$\chi_M$ $Ce^{+++}$	=	$2259.53 \times 10^{-6}$
$\mu_B$ for Y ion	=	$2.839 \sqrt{3441.8 \times 10^{-6} \times 305}$	$\mu_B$ $Ce^{+++}$	=	$2.839 \sqrt{2259.53 \times 10^{-6} \times 305}$
		= 2.909			= 2.356

The values of the effective magnetic moments calculated on the basis of the well known formulae of Hund, Van Vleck and Bose-Stoner are given in Table III along with the observed values of these ions in the case of these periodates.

TABLE III

Ion.	L.	S.	J.	Hund's formula $\sqrt{J(J+L)}$	Van Vleck formula $\sqrt{L(L+1) + 4S(S+1)}$	Bose-Stoner formula $\sqrt{4S(S+1)}$	Obs. magneton values in the periodate <sup>a</sup> .
$Cu^{++}$	2	$\frac{1}{2}$	5/2	3.55	3.01	1.73	1.731
$Ni^{++}$	3	1	4	5.59	4.49	2.83	3.174
$Co^{+}$	3	$1\frac{1}{2}$	9/2	8.83	5.21	3.87	3.67
$Ce^{+++}$	3	$\frac{1}{2}$	5/2	2.54	*2.54	1.732	2.356
$Y^{+}$	2	$\frac{1}{2}$	3/2	2.577	3.0	1.732	2.909

<sup>a</sup> Calculated on the modified formula of Van Vleck.

The observed moments of  $Cu^{++}$  and  $Ni^{++}$  ions in their periodates show that in  $Cu$ , the quenching of the orbital moment is complete, while in  $Ni^{++}$  it is incomplete. The effective magnetic moment of  $Ni$  ion is intermediate between the calculated values on the Van Vleck and Bose-Stoner formulae. In the case of  $Co^{++}$  the magneton value is less than the calculated value from Bose-Stoner formula. This lower value is probably due to an internal magnetic field and it may not accord with the Curie's law. In the values obtained for  $Co^{++}$  by others there is the wide range of the  $P_{CH}$  experimentally found, the results being such that these values depart from the Bose-Stoner formula. Thus Chatillon (*Ann Phys.*, 1928, 19, 187) has shown that  $P_{CH}$  for  $Co^{++}$  depends on the mode of preparation and the history of the material. In our case for periodate the value for  $Co^{++}$  comes to be lower than that recorded by others which possibly makes  $Co^{++}$  a special case for study and theoretical treatment. The value of  $P_{CH}$  in terms of  $\mu_B$  for  $Ce^{++}$  coincides with Hund's formula as expected from the rare earth ion. The moment determinations of the above periodates have shown that the values nearly coincide with those obtained from the theoretical formulae in the same way as the simple salts of other acids do. This shows that these periodates are the true salts of the periodic acids and not the complex salts. In the latter case large deviations between the experimental and theoretically calculated values would have occurred.

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## ORTHO-SUBSTITUTED DIPHENYLS. PART V.

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The methyl ester, ethyl ester, the chloride and the amide of *o*-phenylcinnamic acid have been prepared. *o*-Phenylstyrene has been obtained from *o*-phenylbromostyrene with the intermediate formation of the magnesium compound of *o*-phenylbromostyrene

It has now been possible to prepare a number of derivatives of *o*-phenylcinnamic acid whose preparation has already been described (Zaheer and Faseeh, *J. Indian Chem. Soc.*, 1944, 21, 381). The methyl and ethyl esters have been obtained with concentrated  $\text{H}_2\text{SO}_4$  as the condensing agent in both cases by the method used by Fisher and Spier (*Ber.*, 1895, 28, 3254) to prepare the corresponding ethyl ester of cinnamic acid. With thionyl chloride as the chlorinating agent, *o*-phenylcinnamoyl chloride has been prepared in almost theoretical yield. With cinnamic acid and thionyl chloride, an almost theoretical yield of cinnamoyl chloride also was obtained. The amide has also been prepared from *o*-phenylcinnamoyl chloride in the usual manner.

It was also attempted to prepare indone and phenylindone from cinnamic acid and *o*-phenylcinnamoyl chloride respectively by means of a ring-closure through an internal condensation by the removal of the elements of hydrochloric acid with the agency of aluminium chloride or zinc chloride. Fittig and Erdmann (*Annalen*, 1883, 216, 179) have, however, already noted the failure of cinnamic acid to yield indone by treating with conc.  $\text{H}_2\text{SO}_4$ . Roser (*Annalen*, 1888, 247, 129) suggested that stereochemical isomerism of these compounds might be responsible for this failure to ring-closure, while at the same time certain substituted products, e. g., phenyldichloro-acrylic acid (Zincke *Ber.*, 1887, 20, 1269) and phenyldibromo-acrylic acid (Roser, *Ber.*, 1887, 20, 1273) have been successfully made to yield the corresponding dihalogeno derivatives of indone. Support to Roser's view was lent by the subsequent preparation by Kipping (*J. Chem. Soc.*, 1894, 56, 484) and Braun and Manz (*Annalen*, 1929, 468, 276) of hydrindone and *o*-phenylhydrindone by the action of aluminium chloride on phenylpropionyl chloride and *o*-diphenylpropionyl chloride respectively, where obviously there could be no possibilities of stereochemical isomerism. This observation has been confirmed again by the present

authors who also failed to obtain indone from cinnamoyl chloride. In the case of *o*-phenylcinnamoyl chloride, however, a small yield of a crystalline product (m.p. 242°) was obtained. Both the chlorides gave large quantities of unidentified polymerised products.

The identification of the crystalline product obtained from *o*-phenylcinnamoyl chloride and other products of these reaction awaits further investigation.

The usual method for the preparation of styrene is to distill cinnamic acid in persence of quinol ("Organic Syntheses", 1928, VIII, p 85 ; Higginbottom, "Reactions of Organic Compounds", p. 206). The yields, however, are not good. Another method for the preparation of styrene has been described by Rupe and Proske (*Ber.*, 1910, 43, 1232) by the action of ice-cold dilute sulphuric acid on the magnesium compound of  $\omega$ -bromostyrene, when 55% yield of styrene along with 20% of 1 : 4-diphenylbutadiene (m.p. 147-48°) were obtained. By adopting Rupe and Proske's method it has now been possible to obtain *o*-phenylstyrene by the decomposition of the magnesium compound of *o*-phenyl- $\omega$ -bromostyrene, whose preparation has already been reported (Zaheer *et al.*, *J. Indian Chem. Soc.*, 1947, 24, 57). The yield obtained (57%) is quite satisfactory and very much better than the 24% yield obtained by Bradsher and Wert (*J. Amer. Chem. Soc.*, 1940, 62, 2806) by dehydration through heating for an hour at 160° with potassium bisulphate of the secondary alcohol obtained by the interaction of the magnesium derivative of 2-iododiphenyl with acetaldehyde, but not as good as the 70% yield reported very recently to have been obtained by Huber, Renoll, Rossow and Moury (*ibid.*, 1946, 68, 1111) by the vapour phase dehydration of the same secondary alcohol. In addition to the *o*-phenylstyrene obtained as an oil boiling at 126-29°/3-5mm, a higher boiling point fraction which gave a crystalline solid (m.p. 86-88°) was also obtained in a 9% yield. This has not yet been fully identified but is probably the tetraphenylbutadiene corresponding to diphenylbutadiene obtained by Rupe and Proske (*loc. cit.*).

#### EXPERIMENTAL

*Methyl Ester of o-Phenylcinnamic Acid.*—Absolute methyl alcohol (14g., 10 mol.) was mixed with pure concentrated sulphuric acid (2.2 g., 0.5 mol.) and *o*-phenylcinnamic acid (10g., 1 mol.) gradually added. The ethereal extract of the ester obtained after the usual treatment was dried overnight on anhydrous sodium sulphate.

The ether was distilled off and the residue on distillation under reduced pressure gave a viscous oil, b.p.  $184^{\circ}/4\text{mm.}$ , yield 8.6 g. (81%). (Found: C, 80.80; H, 5.47.  $\text{C}_{16}\text{H}_{14}\text{O}_2$  requires C, 80.67; H 5.88 per cent).

*Ethyl ester of o-phenylcinnamic acid*, obtained in a method as above, gave a colourless viscous oil, b.p.  $195^{\circ}/4\text{mm.}$ , yield 9.5 g. (84%). (Found: C, 81.23; H, 6.11.  $\text{C}_{17}\text{H}_{16}\text{O}_2$  requires C, 80.95; H, 6.35 per cent).

*o-Phenylcinnamoyl Chloride*—*o*-Phenylcinnamic acid (10 g., 1 mol.) was taken in a round flask and thionyl chloride (6g., 1 mol.) added to it carefully. As on mixing, acid fumes ( $\text{HCl}$  and  $\text{SO}_2$ ) were evolved, the reaction was carried out in a fume chamber. An intense cooling effect was produced on mixing the acid with the thionyl chloride and it persisted till the completion of the reaction. At the end of the completion of the reaction (2 hours) the solution was refluxed for 20 minutes on the water-bath and then the condenser was removed and the mixture heated for further 10 minutes, and distilled under filter pump up to a temperature of  $225^{\circ}$  to remove all excess of thionyl chloride. Final distillation under reduced pressure gave a highly viscous, colourless, liquid, b. p.  $182^{\circ}/3\text{mm.}$  which solidified on cooling yield 9 g. (83%). (Found: Cl, 14.51.  $\text{C}_{15}\text{H}_{11}\text{OCl}$  requires Cl, 14.64 per cent).

*o-Phenylcinnamamide*.—*o*-Phenylcinnamoyl chloride was melted in warm water and added in drops to an excess of a concentrated aqueous solution of ammonia when fumes were produced and a white solid separated. The solid was well broken and thoroughly stirred with a glass rod, and left overnight. The contents were filtered, well washed with cold water and finally crystallised from hot water, m. p.  $163\text{--}64^{\circ}$ , yield quantitative. (Found: C, 80.83; H, 5.68; N, 6.24.  $\text{C}_{15}\text{H}_{13}\text{ON}$  requires C, 80.72; H, 5.83; N, 6.28 per cent).

*Magnesium Compound of o-Phenylbromostyrene*.—A solution of *o*-phenyl- $\omega$ -bromostyrene (10 g., 1 mol.) in absolute ether (50 c. c.) was gradually added to magnesium flakes (1.1 g., 1 mol.) covered with absolute ether (50 c. c.). A particle of iodine was added and the air was replaced by nitrogen. The contents were gradually warmed up to  $45^{\circ}$  and were continually stirred and refluxed. Within 15 minutes, the colour due to iodine started disappearing and with the gradual disappearance of magnesium flakes, the solution became turbid and thick within another 30 minutes. At the end of two hours, during which stirring and refluxing were continued and the temperature maintained at  $45^{\circ}$ , no more particles of magnesium were found to disappear and the reaction was assumed to be completed. The solution was made up to



100 c. c. with absolute ether and a 10 c. c. portion was hydrolysed by boiling with 150 c. c. of water and 20 c. c. of standard sulphuric acid. The excess of acid was titrated against standard sodium hydroxide according to the method described by Gilman and Meyer (*J. Amer. Chem. Soc.*, 1923, 45, 159). The quantity of the magnesium compound produced was nearly 80% of the theory.

*o*-Phenylstyrene.—An ethereal solution of the magnesium compound of *o*-phenyl- $\omega$ -bromostyrene (10g., 1 mol.) was prepared as described above. Then an excess of ice-cold dilute sulphuric acid (15%) was added to the solution, which was then well shaken for half an hour, at the end of which it reacted acid to litmus. The solution was then extracted with ether, and the ethereal solution dried overnight over fused calcium chloride. The ether was distilled off and the residue on distillation under reduced pressure gave a colourless oil, b. p. 126-29°/3-5 mm, the yield being 4.1g. (57%). (Found: C 93.45; H, 6.21.  $C_{14}H_{12}$  requires C, 93.33; H, 6.67 per cent).

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BROMINATION OF COMPOUNDS CONTAINING TWO  
AROMATIC NUCLEI. PART VI\*. BROMINATION  
OF ARYL ESTERS OF *m*-CRESOTIC ACID

BY GANPATRAO VISHRAMRAO JADHAV AND MAHOMAD ASLAM

Phenyl, *o*-, *m*-, *p*-cresyl, *m*-, *p*-nitrophenyl and  $\beta$ -naphthyl esters of *m*-cresotic acid have been brominated and their bromo derivatives obtained and the constitution of the compounds, so prepared, confirmed.

Bromination of phenyl, *o*-, *m*-, *p*-cresyl, *m*-, *p*-nitrophenyl and  $\beta$ -naphthyl esters of *m*-cresotic acid has been described. In the case of all other esters except  $\beta$ -naphthyl ester, mono- and dibromo derivatives are obtained by the action of bromine in acetic acid solution, but  $\beta$ -naphthyl ester gives only monobromo derivative in a pure state. Use of liquid bromine gives tribromo compounds in the case of phenyl and *m*-cresyl esters; whilst only the dibromo derivatives of *o*- and *p*-cresyl esters can give the tribromo compounds with liquid bromine. The presence of the NO<sub>2</sub> group in the nitrophenyl esters so completely deactivates the molecule that even with liquid bromine, no bromine can enter the phenolic nucleus. The constitutions of these compounds have been proved by their hydrolysis and confirmed by their preparation by condensing the requisite phenol with the requisite acid.

E X P E R I M E N T A L

*Monobromo Derivatives.*—Solution of bromine in glacial acetic acid (16 c.c. of 20%) was gradually added to the simple ester (4 g.) already dissolved in glacial acetic acid at room temperature, but in the case of nitrophenyl esters, hot solutions were used. The mixture was then shaken for some time when a crystalline bromo derivative separated from the solution. All monobromo derivatives were crystallised from acetic acid. These are described in Table I.

*Dibromo Derivatives.*—The ester (2 g.), dissolved in glacial acetic acid, was heated on a boiling water-bath with bromine solution (4 g. dissolved in 5 c.c. of acetic acid) for about 3 to 4 hours. The bromo derivative separated on cooling. In the case of nitrophenyl esters, however, action of liquid bromine on the ester directly at room temperature, gave better yields. The reaction mixture after some time was diluted with water and excess of bromine removed with sodium bisulphite. They all were crystallised from acetic acid. These are described in Table II.

*Tribromo Derivatives.*—Liquid bromine (10 g.) was added to phenyl or *m*-cresyl ester (4 g.) whilst liquid bromine (5 g.) was added to the dibromo derivative of *o*- or *p*-cresyl ester (5 g.) and the reaction mixture was shaken at room temperature for about an hour and then diluted with water. Excess of bromine was removed by the addition of sodium bisulphite to it and then the product was crystallised from glacial acetic acid. The substances are described in Table III.

*Hydrolysis.*—The hydrolysis of mono and dibromo derivatives was carried out by boiling under reflux the compound with excess of 5% solution of sodium hydroxide for about 3-4 hours. Carbon dioxide was then passed through the cold solution, when the phenolic component separated. This was removed by ether extraction and the aqueous layer gave on acidification with hydrochloric acid, the acid component. The acids were crystallised from acetic acid. They as well as the phenolic components were identified by mixed m.p. with authentic specimens.

In the case of tribromo derivatives, however, they were boiled with 8% solution of sodium hydroxide for about 5 hours and the two components were separated and identified in the same way as above.

\*The previous part of the series, published in the Nov. issue of this Journal (1948) should be read be as Part V and not as Part IV as printed.

*Preparation of Bromo Derivatives by Condensation.*—The monobromo compounds were prepared by heating together for about half an hour 6-bromo-*m*-cresotic acid (4 g.), requisite phenol (3 g.) and phosphorus oxychloride (2.5 c.c.) at 120-125° in the case of phenol and cresols and at 130-135° in the case of nitrophenols and  $\beta$ -naphthol. The reaction mixture was then diluted with water and the solid was washed with dilute alkali. It was crystallised from acetic acid and mixed melting point was taken with the corresponding bromination product, when no lowering was observed.

Dibromo derivatives were similarly obtained from 2 : 6-dibromo-*m*-cresotic acid (4 g.), phenol or cresol (3 g.) or nitrophenol (2 g.) and phosphorus oxychloride (2.5 c.c.) and identified, and tribromo compounds from 2 : 6-dibromo-*m*-cresotic acid (4 g.), *p*-bromophenol, *p*-bromo-*o*-cresol or *p*-bromo-*m*-cresol (2.5 g.) and phosphorus oxychloride (2.5 c.c.) by heating together at 130-135° for about an hour and worked up and identified as above.

TABLE I

B stands for bromobenzoate.

Name of the compounds.	M. p.	Formula.	% Bromine	
			Found.	Calc.
Phenyl 2-hydroxy-4-methyl-5-B	106-7°	C <sub>14</sub> H <sub>11</sub> O <sub>3</sub> Br	25.9	26.0
<i>o</i> -Cresyl 2-hydroxy-4-methyl-5-B	108-9°	C <sub>15</sub> H <sub>13</sub> O <sub>3</sub> Br	24.8	24.9
<i>m</i> -Cresyl 2-hydroxy-4-methyl-5-B	90-9°	C <sub>15</sub> H <sub>13</sub> O <sub>3</sub> Br	25.0	24.9
<i>p</i> -Cresyl 2-hydroxy-4-methyl-5-B	105-8°	C <sub>15</sub> H <sub>13</sub> O <sub>3</sub> Br	24.7	24.9
<i>m</i> -Nitrophenyl 2-hydroxy-4-methyl-5-B	147-48°	C <sub>14</sub> H <sub>10</sub> O <sub>3</sub> NBr	23.0	22.7
<i>p</i> -Nitrophenyl 2-hydroxy-4-methyl-5-B	175-76°	C <sub>14</sub> H <sub>10</sub> O <sub>3</sub> NBr	22.8	22.7
$\beta$ -Naphthyl 2-hydroxy-4-methyl-5-B	143-44°	C <sub>18</sub> H <sub>13</sub> O <sub>3</sub> Br	22.5	22.4

TABLE II

DB-stands for dibromobenzoate.

Name of the compounds.	M. p.	Formula.	% Bromine	
			Found.	Calc.
Phenyl 2-hydroxy-4-methyl-3 : 5-DB	126-27°	C <sub>14</sub> H <sub>10</sub> O <sub>3</sub> Br <sub>2</sub>	41.8	41.5
<i>o</i> -Cresyl 2-hydroxy-4-methyl-3 : 5-DB	167-68°	C <sub>15</sub> H <sub>12</sub> O <sub>3</sub> Br <sub>2</sub>	40.2	40.0
<i>m</i> -Cresyl 2-hydroxy-4-methyl-3 : 5-DB	126-27°	C <sub>15</sub> H <sub>12</sub> O <sub>3</sub> Br <sub>2</sub>	39.9	40.0
<i>p</i> -Cresyl 2-hydroxy-4-methyl-3 : 5-DB	129-30°	C <sub>15</sub> H <sub>12</sub> O <sub>3</sub> Br <sub>2</sub>	40.2	40.0
<i>m</i> -Nitrophenyl 2-hydroxy-4-methyl-3 : 5-DB	188-89°	C <sub>14</sub> H <sub>9</sub> O <sub>3</sub> NBr <sub>2</sub>	38.2	38.4
<i>p</i> -Nitrophenyl 2-hydroxy-4-methyl-3 : 5-DB	219-20°	C <sub>14</sub> H <sub>9</sub> O <sub>3</sub> NBr <sub>2</sub>	38.3	38.4

TABLE III

Name of the compounds.	M.p.	Formula.	% Bromine	
			Found.	Calc.
<i>p</i> -Bromophenyl 2-hydroxy-4-methyl-3 : 5-dibromobenzoate	179-80°	C <sub>14</sub> H <sub>9</sub> O <sub>3</sub> Br <sub>3</sub>	52.0	51.6
2-Methyl-4-bromophenyl 2-hydroxy-4-methyl-3 : 5-dibromobenzoate	182-83°	C <sub>15</sub> H <sub>11</sub> O <sub>3</sub> Br <sub>3</sub>	50.0	50.1
3-Methyl-4-bromophenyl 2-hydroxy-4-methyl-3 : 5-dibromobenzoate	157-58°	C <sub>15</sub> H <sub>11</sub> O <sub>3</sub> Br <sub>3</sub>	49.8	50.1
4-Methyl-2-bromophenyl-2-hydroxy-4-methyl-3 : 5-dibromobenzoate	189-90°	C <sub>15</sub> H <sub>11</sub> O <sub>3</sub> Br <sub>3</sub>	50.0	50.1

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# PRODUCTION OF A STEADY CONDUCTANCE AS A DETERMINANT OF THE JOSHI-EFFECT UNDER SILENT DISCHARGE

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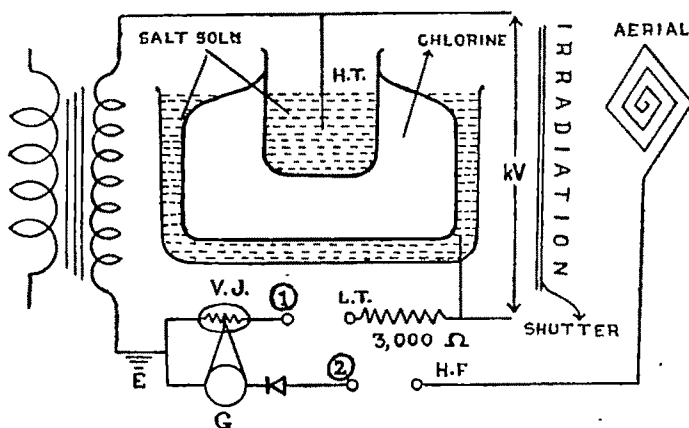
Ageing by exposure to discharge stabilises the discharge current, increasing markedly the *Joshi-effect*  $\Delta i$ , over a wide a range of potentials and using different detectors. The above result and that the high frequency part of the current is the chief seat of  $\Delta i$ , agree with Joshi's theory of the phenomenon. The vacuo-junction is better adapted for  $\Delta i$  detection than a more current-sensitive rectifier.

The time-variation of the discharge current  $i$ , produced by a constant potential kV, applied to an isolated sample of pure chlorine in a sealed ozonizer and especially, of the magnitude of the above phenomenon viz., a reversible and instantaneous current *decrease*,  $\Delta i$  on irradiation was observed under X-rays by Joshi (*Curr. Sci.*, 1944, 13, 278), and under visible light by Deo (*Proc. Indian Acad. Sci.*, 1945, A21, 76), the latter over long periods of discharge. In a recent theory of this effect Joshi (*Proc. Indian Sci. Cong.*, 1946, Part III, p. 25) has postulated that an adsorption-like layer is formed on the electrodes derived, in part, from the gas, activated under the discharge, which plays an important part in the production of  $\Delta i$ . The results of the following work, carried out primarily to study the influence of ageing, are in accord with this conception.

## EXPERIMENTAL

The general procedure was essentially similar to that of Deo (*Proc. Indian Acad. Sci.*, 1943 A19, 117). Fig. 1 shows the apparatus used: A Siemens' type ozonizer (1) filled with purified chlorine was activated at the required potential kV and

FIG 1.



50 cycles frequency. The discharge current,  $i$  was measured with a Cambridge vacuo-junction (V. J. in Fig. 1) connected to a sensitive mirror galvanometer by connecting L. T. with (1). Despite constancy of the applied potential, during time

periods *immediately* after its application,  $i$  was observed to be markedly unstable; no values for the characteristic  $i$  could therefore be obtained. The current,  $i$  was rendered comparatively stable on introducing a 3000 ohm Dubilier resistance between L. T. the low tension electrode of the ozonizer and the detector viz., vacuo-junction (Fig 1). The values for  $i$  (in dark) recorded after every 5 seconds for one series of observations at 10.7 kV, given in Table I, illustrate the position. That an exposure to discharge for 2 hours stabilises conduction is also shown in Table I by the values of  $i$  (in dark) at the above potential and made in precisely the same manner as mentioned earlier.

TABLE I

*Influence of ageing on the discharge current (ozonizer 1).*

Before ageing	4.4	5.2	4.5	5.4	4.8	5.2	5.5	5.3
	5.3	5.0	5.7	5.8	5.7	5.8	5.4	.....
After ageing	7.1	7.1	7.1	7.2	7.2	7.1	7.3	7.1
	7.1	7.1	7.0	7.2	7.3	7.4	7.3	.....

As a sensibly constant current  $i$ , characteristic of the applied potential kV, was observed, the effect of irradiating the ozonizer was studied. This was directed transversely to the ozonizer-axis, using a 200-watt incandescent (glass) bulb. When an opaque shutter (Fig. 1) between this and the ozonizer was raised, so as to let the light fall on the latter,  $i$  showed the Joshi-effect, viz., an instantaneous photo-diminution  $\Delta i$ , restorable to  $i_{\text{dark}}$  on shutting off the light. Several series of observations were taken for this effect  $\Delta i$  at various kV, and after different durations of exposure to the discharge. Table II is a typical group of results. The relative Joshi-effect  $\% \Delta i$  is given by  $\frac{\Delta i}{i_{\text{dark}}} \times 100$ .

TABLE II

*Influence of applied potential on Joshi-effect ( $\Delta i$ ) under steady conductance after ageing (ozonizer 1).*

Applied potential. kV.	$i_{\text{dark}}$ .	$i_{\text{light}}$ .	$\Delta i$ .	$\% \Delta i$ .
9.1	4.9	4.7	0.2	4.1
9.6	5.9	5.4	0.5	8.5
10.2	6.7	6.0	0.7	10.5
10.7	7.5	6.7	0.8	10.7
11.2	8.2	7.3	0.9	11.0
11.8	9.0	7.8	1.2	13.3

A series of observations was next made with ozonizer (2), excited in the range 2 to 8 kV. The discharge current  $i$  was measured with a vacuo-junction (as in the previous series with ozonizer 1); and also separately with a metal oxide type rectifier, connecting L. T. with (2) in Fig. 1. The current and the Joshi-effect  $\Delta i$  and  $\% \Delta i$  were also measured using a moderate size aerial (Fig. 1), kept at a fixed distance near the ozonizer (Joshi, *Nature*, 1944, 154, 147). The aerial currents were observed separately with the vacuo-junction and with the oxide type rectifier, introduced respectively between H. F. and (1); and between H. F. and (2), in Fig. 1. These measurements with the aerial denote the high frequency part of the discharge current which has been shown to be the chief seat of this effect (Joshi, *Curr. Sci.*, 1945, 14, 67).

Using ozonizer (2) ageing under discharge was produced at various durations. Table III summarises one typical set of results, using both the detectors mentioned above. The quantities  $\Delta i$ , and  $\% \Delta i$  observed at a series of kV and at a constant period of ageing are shown in the same vertical column; the above quantities, observed after ageing, are shown within brackets below those, before ageing.

TABLE III

*Variation of current ( $i$ ) and Joshi-effect ( $\Delta i$ ) after different durations of ageing under the discharge (ozonizer 2)*

(Quantities observed after 'ageing' are shown within brackets).

Ageing (in hrs.)	2				2				5			
kV.	$i_{\text{dark}}$	$i_{\text{light}}$	$\Delta i$	$\% \Delta i$	$i_{\text{dark}}$	$i_{\text{light}}$	$\Delta i$	$\% \Delta i$	$i_{\text{dark}}$	$i_{\text{light}}$	$\Delta i$	$\% \Delta i$
(a) A. C. Detector used—vacuo-junction.												
5.9	1.98 (1.95)	1.67 (1.61)	0.31 (0.34)	15.7 (17.4)	1.82 (1.98)	1.52 (1.55)	0.30 (0.48)	16.5 (21.7)	1.90 (1.79)	1.48 (1.15)	0.42 (0.61)	22.1 (34.1)
6.1	2.92 (2.85)	2.51 (2.35)	0.41 (0.50)	14.0 (17.6)	2.57 (3.53)	2.24 (4.11)	0.33 (0.62)	12.8 (20.5)	3.05 (2.81)	2.47 (1.2)	0.58 (0.99)	19.0 (35.2)
6.4	4.20 (4.12)	3.74 (3.45)	0.46 (0.67)	11.0 (16.3)	3.94 (4.30)	3.49 (3.56)	0.45 (0.74)	11.4 (17.2)	4.09 (4.11)	3.42 (2.74)	0.67 (1.37)	16.4 (33.8)
6.7	5.47 (5.27)	4.89 (4.54)	0.58 (0.73)	10.9 (13.9)	5.40 (5.59)	4.97 (4.72)	0.43 (0.87)	8.0 (15.6)	5.53 (5.37)	4.73 (3.77)	0.80 (1.60)	14.5 (29.5)
6.9	6.08 (6.72)	6.02 (5.77)	0.66 (0.95)	9.9 (14.1)	6.50 (6.76)	5.89 (5.78)	0.61 (0.98)	9.4 (14.5)	6.80 (6.75)	5.74 (4.90)	1.06 (1.85)	15.6 (27.4)
7.2	7.98 (8.07)	7.28 (6.95)	0.70 (1.12)	8.8 (13.9)	7.80 (8.08)	7.18 (6.99)	0.62 (1.09)	7.9 (13.5)	8.09 (8.34)	6.91 (6.36)	1.18 (1.98)	14.6 (23.7)
(b) A. C. Detector used—oxide rectifier.												
2.7	3.9 (3.3)	3.9 (3.3)	— —	— —	3.8 (3.5)	3.8 (3.5)	— —	— —	3.7 (3.4)	3.7 (3.4)	— —	— —
4.0	9.8 (8.6)	9.6 (8.4)	0.2 (0.2)	2.0 (2.3)	9.2 (9.3)	9.0 (9.0)	0.2 (0.8)	2.2 (3.2)	9.5 (9.0)	9.2 (8.7)	0.3 (0.3)	3.2 (3.3)
5.3	21.0 (17.8)	20.4 (17.3)	0.6 (0.5)	2.9 (2.8)	19.5 (19.1)	18.6 (18.3)	0.9 (0.8)	4.6 (4.2)	19.4 (18.3)	18.5 (17.4)	0.9 (0.9)	4.6 (4.9)
5.6	26.6 (22.0)	25.1 (20.5)	1.5 (1.5)	5.6 (6.8)	24.5 (25.2)	23.3 (23.9)	1.2 (1.3)	4.9 (5.2)	25.3 (24.1)	23.3 (21.9)	2.0 (2.2)	7.9 (9.1)
5.9	38.6 (33.5)	37.1 (30.5)	1.5 (3.0)	3.9 (8.9)	37.5 (36.7)	34.5 (32.7)	3.0 (1.0)	8.0 (10.9)	38.3 (35.1)	33.8 (28.8)	4.5 (6.3)	11.8 (17.9)
6.1	64.6 (56.0)	61.1 (52.0)	3.5 (4.0)	5.4 (7.1)	57.5 (61.2)	53.5 (54.9)	4.0 (6.3)	6.9 (10.3)	62.8 (56.1)	55.8 (48.1)	7.0 (18.0)	11.1 (23.2)

## DISCUSSION

The results given in Table I show that as an effect of 2 hours' ageing under the discharge,  $i_{\text{dark}}$  is increased sensibly to a constant maximum. Tables I and II show that  $i$ , variable in the range 4.4 to 5.8 (in arbitrary units) was produced at 10.7 kV before ageing and at 9.2 kV afterwards. A series of observations of  $i$  at 5 seconds intervals, before and after ageing as in Table I, shows, however, that its

effect is to stabilise  $i$ , and not necessarily to increase it. This is seen from the results with ozonizer (2) in Table III, for different durations of ageing excited in the range 2 to 8 kV and using two detectors. Such an almost permanent alteration of  $i$  under the large applied fields employed, cannot be ascribed to changes in the ionic mobility, and / or ionic cluster formation (Deo, *Proc. Indian Acad. Sci.*, 1945, A21, 76). Also, no ordinary type of chemical reaction leading to a current change (Joshi, *Curr. Sci.*, 1939, 8, 548) is possible within an elementary gas like chlorine. This alteration in the conductivity suggests the production of a strained or an unstable surface condition of the electrodes under the influence of the operating fields (Joshi, *Proc. Indian Sci. Cong.*, 1943, Part III, p. 51) due, in part, to interaction between the wall material and the activated gas under discharge leading to surface products of a limited life. It is significant to observe that if the discharge was discontinued for say 48 hours, and re-started at the original potential,  $i$  was again found to be unstable and was steadied only after ageing *i.e.*, after a further continued exposure to discharge. Similar results were observed in bromine vapour (Joshi, *loc. cit.*).

The results in Tables I to III also show that  $i$ , rendered steady by ageing, is an optimum condition for the production of the Joshi-effect, at any rate in chlorine at a given applied potential. Using ozonizer (1) the results in Table II show that whilst both  $\Delta i$  and  $\% \Delta i$  increase, the latter changes appreciably slowly (Joshi, *Proc. Indian Acad. Sci.*, 1945, A22, 389) as kV is increased. For ozonizer (2) using a vacuo-junction, the net Joshi-effect,  $\Delta i$  increases with the applied potential varied from 5.9 to 7.2 kV, whereas the corresponding  $\% \Delta i$  decreases (Joshi, *loc. cit.*). There is a marked influence of ageing both on  $\Delta i$  and  $\% \Delta i$ . The increase of  $\Delta i$  with kV during ageing is more rapid; the corresponding decrease of  $\% \Delta i$ , however, is less marked. Under similar conditions of excitation (Table III) when the oxide rectifier is used, considering relatively in a given series,  $\Delta i$  and  $\% \Delta i$  before and after ageing increase first slowly, and then rapidly as the potential is increased from 2.7 to 6.1 kV.

The oxide rectifier is more current sensitive than the vacuo-junction. It was remarkable to observe, however, that whilst the former recorded  $i$  at voltages too small for the vacuo-junction, no Joshi-effect could be observed therewith. At 6.1 kV (Table III)  $i$ , both in dark and in light recorded by the rectifier, is apparently much greater than that observed with the vacuo-junction. It is interesting to note, however, that  $\% \Delta i$ , as observed with the vacuo-junction, is sensibly greater than that with the oxide rectifier. Such a selective behaviour of the oxide rectifier was also observed earlier by Joshi (*Proc. Indian Sci. Cong.*, 1943, Part II, p. 51; *Curr. Sci.*, 1945, 14, 67).

Results for the Joshi-effect are significant when  $i$  in the aerial is observed. For these measurements, the oxide rectifier and a more current sensitive vacuo-junction than that in Tables I-III, were used. Both recorded a comparable aerial current, which represented the high frequency part of  $i$  and the chief seat of  $\Delta i$  (Joshi *Curr. Sci.* 1945, 14, 67). The latter showed about 30% Joshi-effect; that with the former was negligibly small. This difference in the behaviour of the two detectors is strikingly similar to that observed in the L. T. circuit of the ozonizer (Table III), in which the H. F. is the minor component. This may be attributed to the circumstance that the vacuo-junction has a more uniform characteristic than the oxide rectifier (Joshi, *Proc. Indian Acad. Sci.*, 1945, A22, 225), and is subject to the limitations of its rectifying mechanism.

Grateful thanks of the author are due to Prof. S. S. Joshi for his kind help and valuable suggestions during this work.

# CALCULATION OF THE FORMULAE OF THE POLYHALIDES FROM SOLUBILITY DATA

BY ARUN K. DEY

In this paper a new mathematical expression for the calculation of the compositions of complex compounds has been derived from solubility data, and the applicability of the method has been shown by actual calculations from the solubility of halogens in solution of halides.

Formation of a complex is usually inferred by noting the dissolution of an insoluble substance in the presence of a soluble one; but the solubility data have only in a few cases been applied for the elucidation of the composition of the complex ions formed in such solutions, as the method so far applied is not a direct one and involves lengthy and tedious calculations. The formulae of the complexes are first postulated, and then the equilibrium constants are calculated and concurrency of the constants confirms the postulated formulae (*cf* Rosenheim and Steinhäuser, *Z. anorg. Chem.*, 1905, 25, 103; Jakowin, *Z. physikal. Chem.*, 1896, 20, 38).

Halogens have often been observed to dissolve in solution of halides to form complex polyhalides according to the equation,



where H represents the halogen and R, hydrogen or an alkali metal.

Let us assume that the solubility of halogen in water =  $a$  and the solubility of halogen in a solution of halide of concentration,  $c = b$ .

By the law of mass action

$$\frac{[\text{Complex}]}{[RH]^n [H_2]} = K \text{ (equilibrium constant).}$$

At equilibrium point the respective concentrations of

$$[\text{Complex}] = b - a; [H_2] = a; [RH] \text{ used} = (b - a)n; [RH] \text{ unused} = c - (b - a)n$$

$$\therefore \frac{b - a}{(c - bn + an)^n a} = K$$

and for the corresponding concentrations  $a'$ ,  $b'$  and  $c'$ :

$$\frac{b' - a'}{(c' - b'n + a'n)^n a'} = K.$$

Let  $(b - a)$  be represented by  $s$ , and  $(b' - a) = s'$

Hence,

$$\frac{s}{(c - sn)^n a} = K \quad \dots \quad (1)$$

$$\frac{s'}{(c' - s'n)^n a} = K \quad \dots \quad (2)$$

Dividing (1) by (2) we have,

$$\frac{s}{s'} = \left[ \frac{c - sn}{c' - s'n} \right]^n$$

Taking the logarithms of both sides we have,

$$\log \frac{s}{s'} = n [\log (c - sn) - \log (c' - s'n)].$$

Expanding the right hand expression by logarithmic series we have,

$$\log \frac{s}{s'} = n \left[ \left\{ \log c - \frac{s}{c}n + \frac{s^2}{c^2}n^2 - \frac{s^3}{c^3}n^3 + \dots \right\} - \left\{ \log c' - \frac{s'}{c'}n + \frac{s'^2}{c'^2}n^2 - \frac{s'^3}{c'^3}n^3 \right\} \right]$$

or

$$\log s/s' = n[\log c - \log c' - n(s/c - s'/c') \dots \dots \dots].$$



Since  $n$  is dependent on  $c$ , the values of  $s/c - s'/c'$  and those involving higher powers may be neglected for the first approximation. Hence the equation ultimately becomes

$$\log s/s' = n \log c/c'$$

$$\therefore n = \frac{\log s/s'}{\log c/c'} = \frac{\log (b-a)/(b'-a)}{\log c/c'}$$

In the following tables, the values of  $n$  calculated by the expression derived above have been recorded for the complexes formed between (i) iodine and potassium iodide, and (ii) bromine and potassium bromide.

TABLE I.  
*Solubility of I<sub>2</sub> in KI solutions.*  
(Data from Jakowin, *loc. cit.*)

*KI.	*I <sub>2</sub>	$n$ (calc.)	*KI.	*I <sub>2</sub>	$n$ (calc.)
0	1.842	—	13.29	8.003	1.0199
0.930	1.814	0.9203	26.57	14.080	1.0033
1.661	2.235	0.9872	53.15	28.030	1.1528
3.322	3.052	0.9591	106.3	55.280	—
6.643	4.667	1.0299			

\* Concentrations expressed in mg. mole/litre.

From Table I the value of  $n$  works out to be unity, thus showing the formation of KI<sub>3</sub> in the solution. It is interesting to note that the value of  $n$  has a tendency to increase with the increase in concentration of KI, thus indicating the formation of higher polyiodides with increasing quantities of KI.

TABLE II  
*Solubility of Br<sub>2</sub> in KBr solutions at 26.5°.*  
(Data from Worley, *J. Chem. Soc.*, 1905, 87, 1107)

*KBr.	*Br <sub>2</sub> dissolved.	$n$ (calc.)	*KBr.	*Br <sub>2</sub> dissolved.	$n$ (calc.)
0	0.43	—	0.10	0.65	0.9671
0.02	0.47	1.4148	0.20	0.86	0.9658
0.04	0.51	1.0000	0.40	1.27	0.9602
0.06	0.56	1.0000	0.60	1.67	1.0352
0.08	0.59	1.4272	0.80	2.10	1.5118
			0.90	2.935	—

TABLE III  
*Solubility of Br<sub>2</sub> in KBr solution at 18.5°.*  
(Data from Worley, *loc. cit.*)

*KBr.	*Br <sub>2</sub> dissolved.	$n$ (calc.)	*K Br.	*Br <sub>2</sub> dissolved.	$n$ (calc.)
0	0.445	—	0.20	0.87	1.0166
0.02	0.48	1.0996	0.40	1.31	1.0659
0.04	0.52	1.2595	0.60	1.77	1.0360
0.06	0.57	0.9656	0.80	2.23	1.1565
0.08	0.61	0.9732	0.90	2.485	—
0.10	0.65	1.0518	—	—	—

\* Conc. expressed in mg. mole/litre.

The values of  $n$ , as recorded in Tables II and III, show the formation of KBr<sub>3</sub> in all the cases, as the value works out to be unity. Here also there is a tendency of the formation of higher polybromides as shown by the increase in the value of  $n$  with higher concentrations of  $n$ . The fluctuations of the values of  $n$  at other concentrations seem to be due to the experimental errors of the investigators.

It is a pleasure to express my indebtedness to Dr. S. Ghosh, for suggesting these calculations, and to Dr. A. K. Bhattacharya of the University of Saugor, for his kind interest in this work.

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CONDENSATION OF ALDEHYDES WITH AMIDES. PART II.  
AN ADDENDUM. CONDENSATION OF CINNAMALDEHYDE  
WITH *n*-HEPTAMIDE

KANTILAL C. PANDYA AND RAGHUVIR RAJ BHANDARI

In a previous paper (Mehra and Pandya, *Proc. Indian Acad. Sci.*, 1938, 7A, 376, Part II of the series) the condensation of cinnamaldehyde with phenylacetamide, acetamide, benzamide and propionamide have been described, the products being all the *bis*amides. It was also stated that the yields were slightly increased when a trace of pyridine was also taken with them. In the present case the condensation of cinnamaldehyde with *n*-heptamide is described, wherein cinnamylidene-*bis-n*-heptamide is obtained in 42% yield.

Cinnamaldehyde (0.7g.) was heated with 1.4 g. of *n*-heptamide, on a water-bath for 9 hours; the contents began to solidify after 5 hours. Next morning, the product was taken out as usual and recrystallised by means of alcohol and water. After several recrystallisations, the product being each time washed with ether, the pure *bis*heptamide came out as colourless crystals melting at 154-55°. It weighed 0.82 g., the yield being thus 42% of theory.

It is insoluble in water, ether, acetone and cold benzene; soluble in hot alcohol and hot benzene. It does not decolourise bromine water in the cold and Baeyer's reagent and gives no colour with concentrated sulphuric acid, thus confirming its *bis*amide nature. (Found N, 7.6. Cinnamylidene-*bis*heptamide,  $C_{23}H_{36}O_2N_2$  requires N, 7.4%, the corresponding monoamide requires N, 5.75%).

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**Active Nitrogen—A New Theory :** By S. K. MITRA, D. SC., JOYKISSEN  
MOOKERJEE MEDAL LECTURER FOR 1945, INDIAN ASSOCIATION FOR THE CULTIVA-  
TION OF SCIENCE, CALCUTTA, 1945. ROYAL. 8 vo PP. 73 PRICE 5 sh/-.

The book consists of two parts. The first part is a resumé of the characteristic properties and phenomena of active nitrogen studied by different workers ; the second is an enunciation of the author's theory of the nature of active nitrogen molecules, and gives instances where the concept has been useful in explaining observed facts. The author has concluded by making a short reference to what led him to propose his new theory, and by pointing to some yet unexplained facts, e. g., the activity of the "dark modification" and gaps in our knowledge of the subject that have to be filled up.

The book is one of the ablest summaries of the large volume of accumulated experimental material of not infrequently conflicting observations of workers, and especially of the newer and more elaborate methods applied in the second quarter of the century to study the complex phenomenon. The treatment of the problem is illuminating, and the style remarkably lucid.

Since the main purpose of the book, as the name implies, is to acquaint the reader with the author's theory of active nitrogen, other theories have not been as fully treated as one might desire for the purpose of a comparative estimate of their merit. For example, an examination of a suitably modified Sponer's theory is perhaps worthwhile, and might provide a clue to the difficult question of the "dark modification" and to some of the unexplained chemical reactions of the active gas.

The book has been edited and printed with care, with only a few minor errors of print. A notable misprint appears to be  $1/\log I$  (p. 15, line 18 *et seq.*), which should be  $\log 1/I$ , according to the derivation. In the list of references, Strutt's Chemical Society Lecture (*J. Chem. Soc.*, 1918, 113, 200) has been an important omission.

J. G.

**A Text-book of Physical Chemistry :** By DR. N. C. SEN GUPTA & MR.  
K. C. SEN, M. SC. ; MANDAL BROTHERS & Co, LD., CALCUTTA. PRICE Rs 10/-.

The authors are to be congratulated for having brought out a compact volume embracing all the important topics in Theoretical Chemistry within a reasonably small compass. The book contains sixteen chapters covering 525 pages. Each chapter contains a bibliography of relevant literature for further study. Although physical chemistry has been mainly dealt with from the classical angle, as most text-books are, reference has often been made to the newer conceptions, which have brought about such radical changes in our ideas. The chapters on Surface Chemistry and Colloids, Liquid State, Constitution of Molecules, etc. deserve particular mention. Brevity of expression which has been necessitated by limited space has, however, in some places been attained at the cost of clarity and it is hoped that the authors will remedy this defect in a subsequent edition.

On the whole, the book will be specially useful to the B Sc, Honours students of Indian Universities as a preliminary study leading to acquaintance with the more advanced treatises on the subject.

S K. M.

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## PRODUCTION OF THE JOSHI-EFFECT UNDER SILENT ELECTRIC DISCHARGE

By G. S. DESHMUKH

Production of the Joshi-effect  $\Delta i$ , an instantaneous and reversible current decrease, on irradiation even in the visible is observed in a number of gases under (Siemens') ozonizer discharge at 0.1 to 4 kilo volts of 50 and 500 cycles. The effect increases with light-intensity and frequency; is sensitive to pressure changes of the excited gas. Hg vapour abolishes  $\Delta i$  in  $H_2$ .  $\Delta i$  is not observed in neon and diminishes in the order:  $Br > O_2 > air > N_2 > H_2$ , which is approximately the order of their electron affinity, as suggested by Joshi.

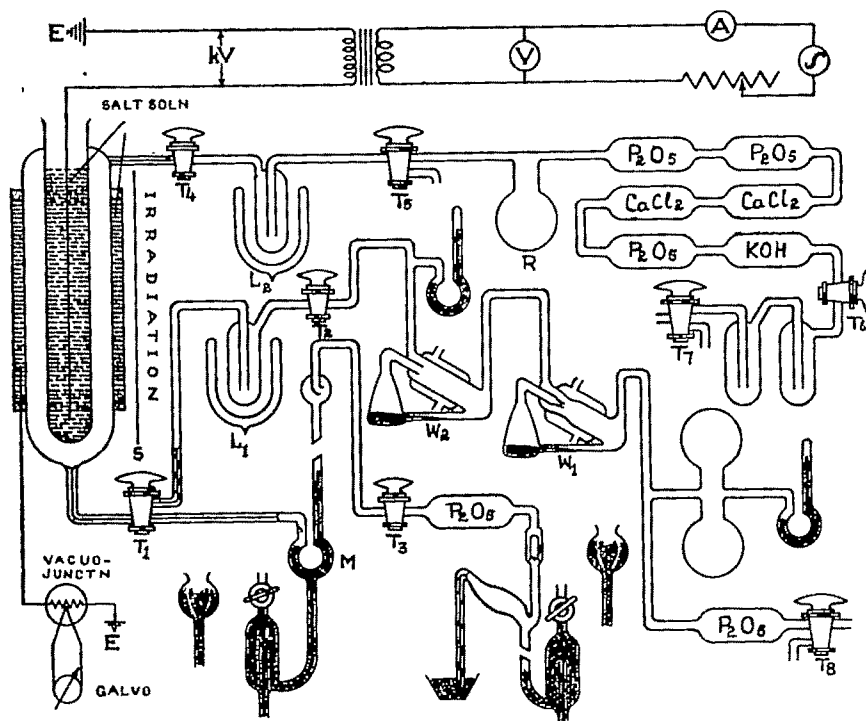
Studies of the behaviour of nitrous oxide by Joshi (*Trans. Faraday Soc.*, 1927, 23, 228; 1929, 25, 10, 118, 137, 143) and later in these laboratories of numerous physico-chemical reactions in various types of electrical discharge (Joshi, *Proc. Indian Sci. Cong.*, 1943, Part II, p. 51; cf. also Joshi, *Curr. Sci.*, 1939, 8, 548) showed the wide applicability of two deductions due to Joshi: (a) a discharge reaction sets in only above a 'threshold potential'  $V_m$ , where the medium breaks down as a dielectric; (b) the corresponding current  $i$  (as also the rate of the associated reaction) depends upon  $V - V_m$ , where  $V$  is the exciting potential. Following results for the  $H_2-Cl_2$  union in electric discharge (Joshi and Bhargawa, *Proc. Indian Sci. Cong.*, 1937, p. 126; Joshi and Narsimhan, *ibid.*, 1939, Part III, p. 57) Joshi observed a photo-increase of  $V_m$  in chlorine. From this and (b), Joshi predicted a current decrease  $\Delta i$  in light, a consequence at variance with the current theories of photo-electric and discharge reactions. This predicted  $\Delta i$  reported by Joshi in 1938 (*vide Joshi, Proc. Ind. Acad. Sci.*, 1945, A 22, 389; *Curr. Sci.*, 1944, 13, 253; Tiwari and Prasad, *ibid.*, 1945, 14, 229; Das-Gupta, *Science & Culture*, 1945, 11, 318) is confirmed by numerous results in these laboratories and elsewhere (especially in  $Cl_2$  in which the *Joshi-effect*  $\Delta i$  is most pronounced) over a wide range of conditions. Extension of  $\Delta i$  to other systems (Joshi and Deshmukh, *Nature*, 1941, 147, 806) restricted by available means, were halted repeatedly by difficulties as the corresponding  $\Delta i$  is much smaller than in  $Cl_2$  and also very sensitive to changes in operative conditions (Joshi and Deo, *Nature*, 1943, 151, 561). This paper reports results for the Joshi-effect  $\Delta i$  in bromine vapour, air,  $N_2$ ,  $O_2$ ,  $H_2$  and Ne in Siemens' tubes.

### EXPERIMENTAL

The general experimental arrangement and the circuit are shown in Fig. 1. The discharge vessel consisted of two glass tubes sealed together co-axially as in a Siemens' ozonizer. This was enclosed in a wooden box with a sliding shutter S; it enabled irradiating the ozoniser without disturbing the rest of the arrangement.

The manometer M recorded the pressure of the gas in the discharge tube. By proper manipulation of the taps  $T_1$ — $T_8$ , the whole or any desired part of the apparatus could be connected to the Töpler and the Warran pumps  $W_1$  and  $W_2$ .

FIG. 1.



The liquid air traps  $L_1$  and  $L_2$  were used for condensing the mercury vapour (which is found to affect the Joshi-effect, vide *infra*) emanating from the Warran pumps and also for freeing the gas under investigation from traces of any other condensible impurities. Each of the gases was dried carefully by leading it slowly through a series of tubes containing phosphorus pentoxide, calcium chloride and potassium hydroxide and stored finally in the reservoir R. The main experiment was commenced only when the entire assembly maintained a satisfactory vacuum for at least 48 hours.

Single phase alternating currents of 50 and 500 cycle frequencies were obtained from rotary converters worked off 220 volt D. C. mains. The output was fed to the primary of a step-up transformer (Fig. 1). One of its secondary terminals was earthed; the other was connected to the high tension i.e. the inner electrode of the ozonizer. The potential in the primary V was recorded with an A. C. voltmeter. The secondary potential kV (kilo volts r.m.s.) was calculated from a knowledge of V and the step-up ratio of the transformer. A reflection type galvanometer, actuated by a Cambridge vacuo-junction, introduced in the low tension part of the ozonizer circuit, served to indicate the current  $i$ . The galvanometer deflections were observed on a scale at 5 meters from the galvanometer; these

readings are accurate to the second decimal place. The current  $i$  was measured (i) in dark and (ii) under irradiation from an external light source, by manipulation of the shutter S, the bulb (or its substitute, *vide infra*) being switched on previously at the desired voltage.

The choice of irradiation depended principally on the nature of the gas under investigation. Thus, for example, in the case of bromine vapour, which showed a comparatively large Joshi-effect  $\Delta i$ , when excited at different applied potentials of 50 cycles frequency, a 220 volt, 200 watt incandescent (glass) bulb was used. With this light-source  $\Delta i$  was scarcely detectable in oxygen, air, nitrogen and hydrogen, excited at 500 cycles frequency. A quartz-mercury vapour lamp of large size was therefore used in their case. This was further supplemented by two large size carbon arcs in the case of neon; for this last, two neon discharge tubes of large size were also used as light source (*cf.* Table VI).

Bromine vapour was obtained from a bulb containing pure liquid bromine. This was first cooled by liquid air when bromine froze to a solid with a negligible vapour pressure. This bulb was then connected to a trap (which was cooled by liquid air) and then to the ozonizer in Fig. 1. This was then evacuated through the taps  $T_1$ — $T_3$  with the Töpler to remove any uncondensable impurities. The liquid air was then removed carefully and bromine allowed to vaporise. The ozonizer was filled with the middle fraction of the vaporised bromine. The bromine bulb was then sealed off. The results for  $\Delta i$  in bromine vapour at about 200 mm. pressure, excited in the range 1-4 kV (50 cycles), are shown in Table I.

TABLE I  
*Joshi-effect in bromine vapour.*

Frequency of the A.C. supply = 50 cycles sec.<sup>-1</sup>  
Source of irradiation = 220 volt, 200 watt bulb.

kV.	(Unpolarised)		$\Delta i$	% $\Delta i$	(Polarised)		$\Delta i$	% $\Delta i$
	Dark.	Light.			Dark.	Light.		
1.3	4.5 (2.12)	4.1 (2.0)	0.12	5.7	4.4 (2.09)	4.2 (2.04)	0.05	2.4
1.8	6.2 (2.49)	5.6 (2.36)	0.13	5.2	6.0 (2.45)	5.8 (2.36)	0.09	3.7
2.7	10.1 (3.18)	8.8 (2.96)	0.22	6.9	9.8 (3.13)	8.9 (2.98)	0.15	4.8
3.5	14.8 (3.84)	12.7 (3.56)	0.28	7.8	14.0 (3.74)	12.3 (3.5)	0.24	6.8

Oxygen was obtained by heating pure potassium chlorate in a small, hard glass bulb sealed to the apparatus. The bulb containing the chlorate was evacuated thoroughly and then heated slowly just above the fusion temperature of the chlorate. The first portion of the evolved gas was rejected by the Töpler; the middle portion was passed over heated magnesium powder to remove any traces of nitrogen. The gas was dried carefully over phosphorus pentoxide and then admitted to the

ozonizer at the desired pressure by the manipulation of the taps  $T_4$  and  $T_5$  in Fig. 1. Since compared with bromine,  $\Delta i$  was very much smaller in other gases, the frequency of the A.C. supply used was increased to 500 cycles with all of them; this greatly increased the current  $i$  at the same applied  $V$ . The observation of the corresponding current change was expected therefore to be more accurate. Table II refers to the results obtained for  $\Delta i$  in oxygen at 22 and 36 mm. pressures at 0.1 to 0.4 kV applied to the ozonizer.

TABLE II

*Joshi-effect in oxygen.*

Frequency of the A.C. supply = 500 cycles sec.<sup>-1</sup>.

Source of irradiation = Mercury vapour lamp.

Pressure of O <sub>2</sub> =2.2 cm. Hg.					Pressure of O <sub>2</sub> =3.6 cm. Hg				
kV.	Galvo deflection		$\Delta i$ .	% $\Delta i$ .	kV.	Galvo deflection		$\Delta i$	% $\Delta i$ .
	Dark.	Light.				Dark.	Light.		
0.18	48.0 (6.92)	44.0 (6.63)	0.29	4.2	0.16	44.0 (6.63)	48.2 (6.57)	0.06	0.9
0.21	102.0 (10.1)	94.5 (9.72)	0.38	3.7	0.21	97.0 (9.84)	93.5 (9.66)	0.18	1.8
0.27	123.0 (11.09)	114.0 (10.68)	0.41	3.7	0.27	115.0 (10.72)	109.0 (10.44)	0.28	2.4
0.32	151.0 (12.29)	141.5 (11.9)	0.39	3.1	0.32	142.0 (11.92)	132.6 (11.51)	0.42	3.5

Air was freed carefully from carbon dioxide and moisture by leading it slowly through a train of tubes containing potassium hydroxide, phosphorus pentoxide and calcium chloride. The data for the Joshi-effect at 0.2 to 0.4 kV of 500 cycles frequency in air are shown in Table III.

TABLE III

*Joshi-effect in air.*

Frequency of the A.C. supply = 500 cycles sec.<sup>-1</sup>.

Source of irradiation = Mercury vapour lamp.

Pressure of air=2.8 cm. Hg.					Pressure of air=3.8 cm. Hg.				
kV.	Galvo deflection		$\Delta i$ .	% $\Delta i$ .	kV.	Galvo deflection		$\Delta i$ .	% $\Delta i$ .
	Dark.	Light.				Dark.	Light.		
0.27	46.0 (6.78)	43.2 (6.57)	0.21	3.1	0.27	41.0 (6.04)	40.8 (6.02)	0.02	0.3
0.35	86.0 (9.27)	81.5 (9.02)	0.25	2.7	0.32	74.0 (8.6)	72.5 (8.51)	0.09	1.0
0.37	119.0 (10.91)	113.5 (10.65)	0.26	2.4	0.37	96.0 (9.8)	93.5 (9.68)	0.12	1.2
0.40	131.0 (11.45)	124.0 (11.14)	0.31	2.7					

Nitrogen was obtained from a commercial cylinder. The gas was bubbled carefully through a series of absorption bulbs containing a freshly prepared solution of alkaline pyrogallol and then led very slowly over strongly heated copper turnings to remove traces of oxygen. This gas was dried carefully over phosphorus pentoxide and then introduced in the ozonizer. Results for  $\Delta i$  at 0.2 to 0.5 kV of 500 cycles frequency in nitrogen are given in Table IV.

TABLE IV

*Joshi-effect in nitrogen.*

 Frequency of the A.C. supply = 500 cycles sec.<sup>-1</sup>.

Source of irradiation - Mercury vapour lamp.

 Pressure of N<sub>2</sub> = 2.6 cm. Hg.

 Pressure of N<sub>2</sub> = 4.1 cm. Hg.

Galvo deflection					Galvo deflection				
kV.	Dark.	Light.	$\Delta i$ .	% $\Delta i$ .	kV.	Dark.	Light.	$\Delta i$ .	% $\Delta i$ .
0.21	85.0 (5.91)	34.0 (5.83)	0.08	1.3	0.24	18.0	18.0	—	—
0.27	58.0 (7.61)	55.5 (7.45)	0.16	2.1	0.32	31.0 (5.56)	30.2 (5.49)	0.07	1.26
0.32	76.0 (8.71)	72.5 (8.51)	0.20	2.2	0.37	41.5 (6.44)	39.0 (6.24)	0.20	3.1
0.37	94.0 (9.7)	90.0 (9.48)	0.22	2.2	0.43	51.0 (7.4)	48.0 (6.92)	0.22	3.1

Hydrogen was prepared by the electrolysis of a dilute aqueous solution of pure baryta. The gas was bubbled slowly through a freshly prepared solution of alkaline pyrogallol and then over heated copper turnings and magnesium powder, in order to remove any traces of oxygen and nitrogen respectively. It was then dried by passing over phosphorus pentoxide and calcium chloride and finally admitted to the ozonizer at the desired pressure. Data for the Joshi-effect in hydrogen at 500 cycles frequency in the range 0.1 to 0.4 kV are recorded in Table V. In observing the influence of mercury vapour on the corresponding Joshi-effect in hydrogen, the apparatus was evacuated as described earlier without cooling the traps L<sub>1</sub> and L<sub>2</sub> by liquid air, which served to condense mercury; instead, hydrogen was led over heated mercury in the Warran pumps W<sub>1</sub> and W<sub>2</sub> before entering the ozonizer. As shown in the lower half of Table V,  $\Delta i$  was not detectable on saturating hydrogen at 34 mm. pressure with mercury vapour.

TABLE V

*Joshi-effect in hydrogen.*

 Frequency of the A. C. supply = 500 cycles sec.<sup>-1</sup>

Source of irradiation = Hg vapour lamp.

 Pressure of H<sub>2</sub> = 1.7 cm. Hg.

 Pressure of H<sub>2</sub> = 6.7 cm. Hg.

Galvo deflection					Galvo deflection				
kV.	Dark.	Light.	$\Delta i$ .	% $\Delta i$ .	kV.	Dark.	Light.	$\Delta i$ .	% $\Delta i$ .
0.13	88.0 (9.38)	87.0 (9.32)	0.06	0.06	0.21	19.0	19.0	—	—
0.16	131.0 (11.45)	128.0 (11.30)	0.15	1.3	0.27	79.0	79.0	—	—
0.19	150.0 (12.24)	144.0 (12.0)	0.25	2.4	0.30	140.6	140.6	—	—
0.20	185.0 (13.6)	176.0 (13.27)	0.33	2.4	0.32	186.0	186.0	—	—



TABLE V (contd.)

Pressure of $H_2=3.3$ cm. Hg.					Pressure of $H_2$ (mixed with Hg vapour) =3.4 cm. Hg.				
kV.	Galvo deflection		$\Delta i$ .	% $\Delta i$ .	kV.	Galvo deflection		$\Delta i$ .	% $\Delta i$ .
	Dark.	Light.				Dark.	Light.		
0.13	46.0 (6.78)	45.4 (6.73)	0.05	0.7	0.18	43.0	43.0	—	—
0.16	126.0 (11.22)	123.0 (11.09)	0.13	1.1	0.16	105.0	105.0	—	—
0.19	168.0 (12.96)	165.0 (12.84)	0.12	0.9	0.19	174.0	174.0	—	—
0.27	204.5 (14.3)	198.5 (14.1)	0.20	1.3					

In experiments with neon the ozonizer was first evacuated as completely as possible using Töpler and Warran pumps. A high frequency discharge was passed through the ozonizer and the process of evacuation continued to ensure complete removal of any traces of impurities adsorbed on the walls of the ozonizer. Neon was then introduced at a small pressure and subjected to electrical discharge and the system was again evacuated. This process was repeated till a spectroscopically pure sample of the gas was obtained in the ozonizer. The gas pressure employed was 23 mm. These results for neon, excited in the range of 0.1 to 1.0 kV (500 cycles) and irradiated by a quartz-mercury vapour lamp, two carbon arcs and neon discharge tubes (all of large size), are shown in Table VI.

TABLE VI

*Joshi-effect in neon.*Frequency of the A. C. supply = 500 cycles sec.<sup>-1</sup>

Pressure of neon = 2.3 cm. Hg.

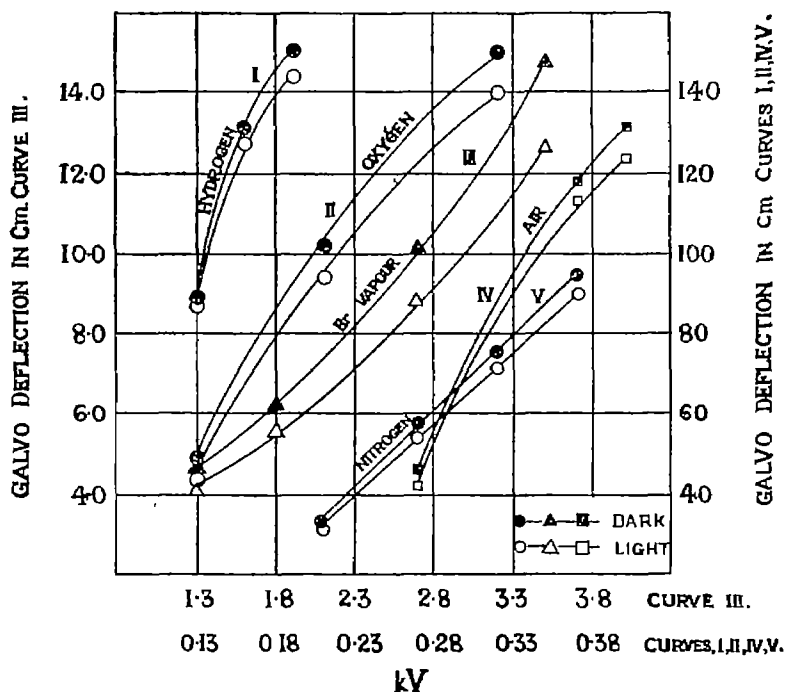
 $\Delta i$  & %  $\Delta i$  — nil.

Source of irradiation = Hg vapour lamp.			Source of irradiation = 2 carbon arcs.			Source of irradiation = 2 Neon discharge tubes.		
kV.	Galvo deflection		kV.	Galvo deflection		kV.	Galvo deflection	
	Dark.	Light.		Dark.	Light.		Dark.	Light.
0.18	3.0	3.0	0.43	14.0	14.0	0.59	8.0	8.0
0.16	11.2	11.2	0.50	25.0	25.0	0.83	47.6	47.6
0.21	16.6	16.6	0.59	47.0	47.0	0.88	102.0	102.0
			0.67	56.0	56.0		172.0	172.0
			0.83	102.0	102.0			
			1.0	173.0	173.0			

Fig. 2 shows characteristic current deflection-potential curves for the above gases in dark and in light with appropriate scale units (*cf.* Tables I-VI). The discharge current  $i$  is given by the square root of the corresponding deflection in Fig. 2 (and shown within brackets under the corresponding deflections in Tables I-VI), the decrease of  $i$  in dark under light gives the net Joshi-effect  $\Delta i$  under given

conditions ; the relative Joshi-effect is shown by  $\% \Delta i$ . It is seen, *e.g.*, in the case of bromine vapour (Table I) that the decrease (under light) in the current deflection is 9 to 14% as the applied potential is increased from 1.3 to 3.5 kV. The much less reduced values for  $\% \Delta i$  are due to the circumstance that  $i$  depends upon the

FIG 2.



square root of the corresponding galvanometer deflection ; this renders both  $\Delta i$  and  $\% \Delta i$  more accurate than the deflection changes on irradiation. The quantities  $\Delta i$  and  $\% \Delta i$ , as reported in Tables I-VI, are such that changes in deflection less than five times the accuracy of observation are not considered.

## DISCUSSION

The foregoing results serve to establish that (under the range of operative conditions employed in this work) with the exception of neon, the Joshi-effect  $\Delta i$  occurs in the various gases investigated, viz., bromine, oxygen, air, nitrogen and hydrogen. An appreciable  $\Delta i$  is to be anticipated in bromine vapour by analogy of its nature with chlorine. That  $\Delta i$  characteristic of bromine is much greater than that in any of the other gases, now studied, is shown by the fact that, it is 5.7% (*cf.* Table I) with light from a 200 watt bulb and a current of 50 cycles frequency ; whereas  $\Delta i$  is not detected in any of the other gases using mercury arc irradiation, which has a far greater intensity, both over-all and in the short wave

(therefore, photoactive) region. Also even with this light, in contrast with bromine,  $\Delta i$  was observable in any of the above gases only when the total conductivity was enhanced by using a much larger current frequency, viz., 500 cycles; with this last and the bulb light  $\Delta i$  was not observed in the above gases.

The characteristic current-potential curves for dark and light in Fig. 2, show that the net Joshi-effect  $\Delta i$  in any gas increases by increasing the applied potential kV. The corresponding relative effect  $\% \Delta i$ , however, diminishes over the potential range investigated, viz., 0.1 to 4 kilo volts (r.m.s.) except in the case of bromine vapour. Subsequent work has shown that  $\% \Delta i$  even in bromine diminishes with a large enough applied potential; this has been specified to be a general characteristic of this phenomenon by Joshi (*loc. cit.*).

Joshi (*loc. cit.*) and Joshi and Deo (*loc. cit.*) have emphasized that  $\Delta i$  is determined by several factors, e.g., nature of the electrode surface, its area, spacing and 'ageing' under the discharge, various electrical quantities, nature, temperature and especially the pressure of the excited gas (Joshi and Deo, *Nature*, 1944, 153, 434).

The chief difficulty in ascertaining the optimum conditions for  $\Delta i$  and its comparative values in different gases, is that more than a restricted change of one of these factors alters the magnitude of others and therefore reduces the comparability of results. The following deduction can, however, be made from results in Fig. 2: With mercury arc light a gas pressure varied over 25 to 35 mm. Hg, excited over 0 to 0.3 kV of 500 cycles, the Joshi-effect  $\Delta i$  varies in the order: oxygen > air > nitrogen > hydrogen. That  $\Delta i$  in bromine vapour exceeds markedly that in any of the other gases studied has been shown already. The above order for  $\Delta i$  in the various gases would appear to be also their order in respect of the 'electron affinity', which has been emphasized by Joshi to be an important determinant of  $\Delta i$ . Their relative adsorbability (both ionic and molecular, on the excited walls of the ozonizer) is possibly another factor. This is also suggested by the marked influence on  $\Delta i$  of saturating hydrogen with mercury vapour (Table V). Work is in progress to investigate this result in more detail. It is also seen that  $\Delta i$  is more pronounced at a low initial pressure  $p$ . The apparent reduction in  $\Delta i$  with bromine vapour (Table I) with light transmitted through a polaroid has been attributed to the reduction of the corresponding intensity as distinct from an effect due to light polarisation. The production of  $\Delta i$  in gases other than halogens suggests that it may be different from the well known Budde effect.

Results recorded in Table VI (of only one typical series) show that within the limitations of these experimental conditions the Joshi-effect  $\Delta i$  is absent in excited neon despite the various intense irradiations employed. The possibility of  $\Delta i$  being due to destruction of the metastable atoms was examined in the case of hydrogen (*cf.* Table V). Penning (*Phil. Mag.*, 1931, 11 961) has found that about 0.0001% of mercury vapour reduced the 'starting potential' of neon by about 20%. The energy of the metastable neon atom viz., 16.6 volts is sufficient for the ionisation

of mercury, which occurs at 10.4 volts. When, however, the mixture is exposed to an external neon light, the metastable neon atoms are considered by Penning to be destroyed and the corresponding starting potential is raised as a consequence. Since the ionisation potential of mercury is less than that of hydrogen viz., 13.3 volts, an increase of the 'starting potential' and therefore on Joshi's view that  $i$  depends on  $(V-V_m)$ , a current decrease like  $\Delta i$  should occur in the hydrogen mercury vapour mixture on irradiation. The negative results using a quartz-mercury vapour lamp (Table V) seem therefore to discriminate the Joshi-effect from the phenomenon observed by Penning. Similar observations are not possible with bromine vapour, oxygen and air in view of a possible chemical reaction between mercury and these gases.

Grateful thanks of the author are due to Prof. S. S. Joshi for suggesting the problem and kind guidance during the work.

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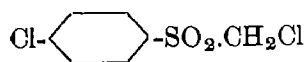
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## STUDIES IN SULPHONES. PART III.\* SYNTHESIS OF NEW CONTACT INSECTICIDES†

BY B. C. JAIN, B. H. IYER AND P. C. GUHA

Syntheses of *p*-chlorophenylchloromethylsulphone, the active principle of the German insecticide "Leuseto neu" and five of its analogues have been described.

Busvine (*Nature*, 1946, 158, 22) has shown that the active principle of the new type of German insecticide "Leuseto neu" used during the World War II, is *p*-chlorophenylchloromethylsulphone.



Although it is more toxic to lice and bed-bugs than D. D. T., it suffers from the disadvantage that its solubility in mineral oil is low. No details of the synthesis of this compound are yet available. Since this opens up fresh field for research on synthetic insecticides, it was thought of interest to synthesise this and a few analogous compounds.

By reacting the sodium salt of *p*-acetaminobenzene sulphinic acid ("Organic Synthesis", Coll. vol. I, p.8) with dichloroacetic acid, *p*-acetaminophenylchloromethylsulphone (I) is obtained. This on hydrolysis with hydrochloric acid gives *p*-aminophenylchloromethylsulphone (II).

Compound (II) on diazotisation and further subjecting to Sandmeyer's reaction yields *p*-chlorophenyl- (III), *p*-bromophenyl- (IV), and *p*-iodophenyl- (V) chloromethylsulphones. Sandmeyer's reaction using cuprous cyanide for the synthesis of *p*-CN-substituted analogue does not take place in a facile manner. On heating the diazonium solution of (II), *p*-hydroxyphenylchloromethylsulphone (VI) is obtained.

Dichloroacetic acid reacts with *p*-chlorobenzene sulphinic acid in alkaline solution to form the unstable chlorophenylchlorocarboxymethylsulphone (not isolated) which furnishes *p*-chlorophenylchloromethylsulphone (III) by the elimination of one molecule of carbon dioxide.

It is interesting to record that the insecticidal action of *p*-chlorophenylchloromethylsulphone in the case of the very common weevil (*Calandra oryzae*) affecting rice, wheat and jowar in storage, has been found to be very unsatisfactory, the average percentage mortality after 72 hours of exposure being not more than 37, even at 100% concentration, the material having been intimately mixed

\* A preliminary note was published in *Science & Culture*, 1947, 12, 405.

† The two previous parts in the series are :

Part I : *J. Indian Chem. Soc.*, 1947, 24, 194. (cf., *Science & Culture*, 1945, 11, 587 ).

Part II : A note on the Preparation of Promin ( *Science & Culture*, 1945, 11, 568 ).

with jowar at the rate of 1 oz. for every 100 pounds. This finding raises the question if *p*-chlorophenylchloromethylsulphone is highly selective in its insecticidal action or if it is really the active constituent of *Leuseto neu*. The problem requires further scrutiny.

### EXPERIMENTAL

*p*-Acetaminophenylchloromethylsulphone (I).—*p*-Acetaminobenzene sulphinic acid (20 g) and dichloroacetic acid (13 g.) were dissolved in water (100 c. c.) containing sodium hydroxide (8.5 g) and heated under reflux. After 2 hours a precipitate separated out. This was filtered on cooling and the filtrate was again refluxed for another 6 hours when a further quantity of precipitate was thrown out. This was collected and combined with the first lot, washed with water and crystallised from dilute alcohol, m.p. 204-205°, yield 16 g. The product gave no effervescence with sodium bicarbonate indicating that decarboxylation also had occurred.

The same product was obtained even when the reaction was carried out with two molecular proportion of *p*-acetaminobenzene sulphinic acid to one of dichloroacetic acid. (Found : N, 5.6.  $C_9H_{10}O_3NClS$  requires N, 5.65 per cent).

*p*-Aminophenylchloromethylsulphone (II).—Compound (I, 12 g.) was refluxed with 5*N*-HCl (120 c.c.) for 2 hours. The resulting solution, on cooling, was neutralised with ammonia when a colourless crystalline precipitate was obtained. This was collected, washed with water and crystallised from dilute alcohol, m.p. 98°, yield 9.5 g. (Found : N, 6.75.  $C_7H_8O_2NClS$  requires N, 6.8 per cent).

*p*-Chlorophenylchloromethylsulphone (III).—(a). Compound (II, 5 g.) dissolved in 5*N*-HCl (25 c.c.) was diazotised in the usual manner with sodium nitrite (2 g) dissolved in water (10 c.c.). Cuprous chloride solution (30 c.c., 10%) was then added to the diazonium solution and it was refluxed until evolution of nitrogen ceased. It was then cooled and the precipitate separating was collected, washed with water and crystallised from dilute alcohol, m.p. 120°, yield 4 g. (Found : S, 14.2.  $C_7H_6O_2Cl_2S$  requires S, 14.3 per cent).

(b). *p*-Chlorobenzene sulphinic acid (8.9 g.), prepared according to Gattermann (*Ber.*, 1899, 32, 1142; 1908, 41, 3320) and dichloroacetic acid (6.5 g.) were dissolved in water (50 c.c.) containing sodium hydroxide (4.5 g.) and boiled under reflux for 8 hours when a crystalline precipitate separated. This was collected, washed with water and crystallised from dilute alcohol, m.p. 120°, yield 6 g. It did not give effervescence with sodium bicarbonate. Carbon dioxide was evolved from the alkaline mother-liquor on acidification. The same compound resulted when the reaction was conducted with two molecular proportion of *p*-chlorobenzene sulphinic acid. There was no depression in melting point on admixture with the product prepared as detailed in (a).

*p*-Bromophenylchloromethylsulphone (IV).—A solution of cuprous bromide, prepared from copper sulphate (4.15 g.), potassium bromide (12 g.), water (25 c.c.), conc. sulphuric acid (4 g.) and copper turnings (8 g.) was added to the diazonium solution obtained from compound (II, 5 g.) as detailed under (a) above, and boiled under reflux until evolution of nitrogen ceased and the product worked out in the usual manner. m.p. 145–46°, yield 4.4 g. (Found : S, 11.61.  $C_7H_6O_2ClBrS$  requires S, 11.87 per cent).

*p*-Iodophenylchloromethylsulphone (V).—A solution of potassium iodide (10 g.) in water (15 c.c.) was added to the diazonium solution obtained from compound (II, 5 g.) and the product worked out as in (IV), m.p. 172°, yield 5 g. (Found : S, 10.12.  $C_7H_6O_2ClIS$  requires S, 10.10 per cent).

*p*-Hydroxyphenylchloromethylsulphone (VI).—The diazonium solution from compound (II, 10 g.) on being heated on a water-bath for 2 hours gave the product which was crystallised from dilute alcohol, m.p. 144°, yield 8.2 g. (Found : S, 15.32.  $C_7H_7O_3ClS$  requires S, 15.5 per cent).

Our thanks are due to B. Krishnamurti Esq., B. Sc., F.R.E.S., Entomologist to the Government of Mysore, for kindly testing the insecticidal action of *p*-chlorophenylchloromethylsulphone.

One of the authors (B.C.J.) wishes to express his thanks to the Lady Tata Memorial Trust for the award of a scholarship which enabled him to participate in this research.

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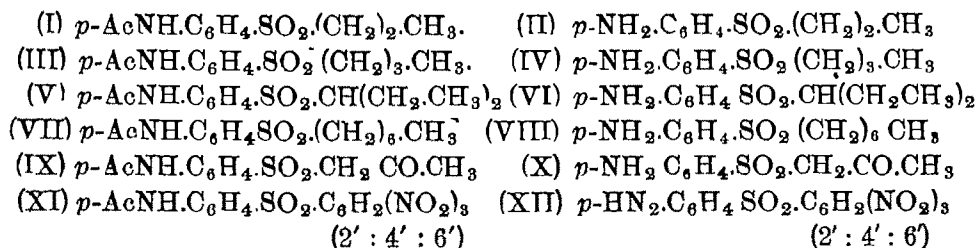
## STUDIES IN SULPHONES. PART IV. SOME SUBSTITUTED ALKYL-ARYL AND DI-ARYL SULPHONES\*

BY B. C. JAIN, B. H. IYER AND P. C. GUHA

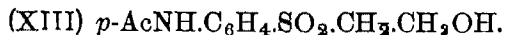
By reacting sodium *p*-acetaminobenzene sulphinate with various alkyl halides, monochloroacetone, picryl chloride, *p*-nitrobenzyl bromide, ethylene chlorhydrin, benzoquinone and thymoquinone, the corresponding unsymmetrical sulphones have been synthesised. The action of diethyl bromomalonate and dicyandiamide on 4-nitro-4'-aminodiphenylsulphone has also been studied.

In continuation of our studies in sulphones (Jain, Iyer and Guha, *Science & Culture*, 1945, 11, 567, 568) we have now synthesised twenty new compounds detailed below.

By reacting the sodium salt of *p*-acetaminobenzene sulphinnic acid ("Organic Synthesis", Coll. vol. I, p. 8) with propyl, butyl, *iso*amyl and heptyl halides as also with monochloroacetone and picryl chloride, the respective *p*-acetaminophenyl alkyl sulphones (I), (III), (V), (VII), (IX) and (XI) were obtained. They were hydrolysed with hydrochloric acid to the corresponding *p*-aminophenyl alkyl sulphones (II), (IV), (VI), (VIII), (X) and (XII) respectively. Walker (*J. Chem. Soc.*, 1945, 630) has prepared (IX) and reported its melting point as 91-92°, whereas our observed m. p. is 115°. We have repeated Walker's experiment and observed that the pure product actually melts at 115° which is the same as recorded by Sikdar (*J. Indian Chem. Soc.*, 1946, 23, 203) whose paper came to our notice after we completed the work.



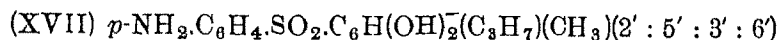
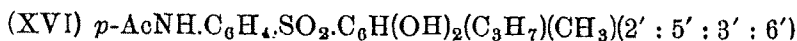
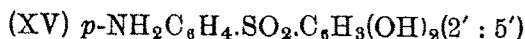
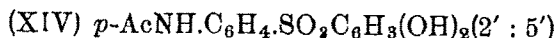
*p*-Acetaminophenyl- $\beta$ -hydroxyethylsulphone (XIII) has been prepared by the action of ethylene chlorhydrin on sodium *p*-acetaminobenzene sulphinate. This could not be hydrolysed to the corresponding amino derivative owing to cleavage of the molecule on treatment with acid.



\* A preliminary note was published in *Science & Culture*, 1947, 12, 406.

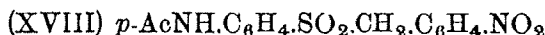


By reacting sodium *p*-acetaminobenzene sulphinate with benzoquinone and thymoquinone according to the method of Hinsberg (*Ber.*, 1894, 27, 3259 ; 1895, 28, 1315) the acetyl compounds (XIV), (XVI) and the corresponding hydrolysed products (XV) and (XVII) are obtained.

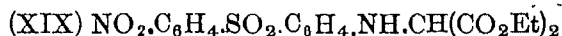


After we had completed the work, we saw the paper on "The reaction between aromatic sulphinic acids and quinones and quinoneimines" by Pickolz (*J. Chem. Soc.*, 1946, 685) which reached us on 27th October, 1946. While Pickolz also has obtained products (XIV) and (XV), he has reported (contrary to our experience and Hinsberg's claim) that the reaction with thymoquinone could not be effected.

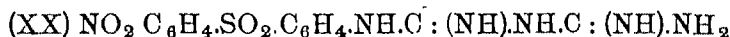
*p*-Acetaminophenyl-*p*'-nitrobenzylsulphone (XVIII) has been prepared by the action of *p*-nitrobenzyl bromide on sodium *p*-acetaminobenzene sulphinate. The product decomposes on hydrolysis.



By the action of diethyl bromomalonate on 4-amino-4'-nitrodiphenylsulphone, 4-dicarbethoxymethylamino-4'-nitrodiphenylsulphone (XIX) is obtained. Attempts to hydrolyse, reduce or condense the product with urea led to its cleavage. It is of interest to record that when sodium *p*-acetaminobenzene sulphinate is reacted with diethyl bromomalonate, a high melting product, insoluble in all solvents, and yielding sulphanic acid as a cleavage product on treatment with dilute sodium hydroxide in the cold, results



When the hydrochloride of 4-amino-4'-nitrodiphenylsulphone is fused with dicyandiamide, 4-biguanyl-4'-nitrodiphenylsulphone (XX) results.



## EXPERIMENTAL

*Preparation of Acetaminosulphones.*—Sulphones (I), (III), (V), (VII), (IX) and (XI) were prepared by reacting *p*-acetaminobenzene-sodium sulphinate with excess of the respective halogen compound in presence of alcohol. While in the reaction leading to the formation of sulphone (XIII) no solvent was used, *isoamyl* alcohol was employed for preparing sulphone (XVIII). The general procedure is as follows.

*4-Acetaminophenylpropylsulphone* (I).—*p*-Acetaminobenzene sodium sulphinate (9 g.), propyl iodide (8 g., excess) and alcohol (20 c. c.) were heated under reflux for 20 hours. Excess of the halide was then removed by steam and the resulting solid collected, washed with water and crystallised from dilute alcohol, m. p. 135°, yield 10.5 g. It is soluble in ethyl acetate, pyridine and acetic acid.

Sulphones (XIV) and (XVI) were prepared from benzoquinone and thymoquinone respectively, according to details given under (XIV).

*4-Acetaminophenyl-2' : 5'-dihydroxyphenylsulphone* (XIV).—Benzoquinone (2.16 g.) was added in small quantities to a boiling solution of *p*-acetaminobenzene sodium sulphinate (4 g.) in water (100 c. c.) and the heating continued for 15 minutes when the colour of the quinone was discharged and a pink precipitate resulted. After cooling, this was collected, washed with water and crystallised from alcohol, m. p. 271-72°, yield 5.2 g.

*Hydrolysis of Acetaminosulphones*.—Sulphones (II), (IV), (VI), (VIII), (X), (XII), (XV) and (XVII) were obtained by hydrolysing the corresponding acetaminosulphone with 5*N*-HCl as detailed under (II).

*4-Aminophenylpropylsulphone* (II).—Sulphone (I, 5 g.) was refluxed with 5*N*-HCl (50 c. c.) for 2 hours and the solution was cooled and neutralised with ammonia. The resulting precipitate was collected, washed with water and crystallised from alcohol, m. p. 99-100°, yield 3.8 g.

*Sulphones* (XIX) and (XX): *4-Nitrophenyl-4'-dicarbethoxymethylaminophenylsulphone* (XIX).—4-Nitro-4'-aminodiphenylsulphone (7 g.), diethyl bromomalonate (6 g.) and alcohol (20 c. c.) were heated under reflux on a water-bath for 16 hours. Alcohol was then removed by distillation under vacuum and the residue, on treatment with benzene, gave a precipitate. This was collected, washed with benzene and crystallised from alcohol, m. p. 145° (decomp.), yield 7.5 g. It is soluble in alcohol, pyridine and acetic acid; insoluble in water, ether and benzene. On hydrolysis with HCl 4-nitro-4'-aminodiphenylsulphone was obtained.

*4-Nitrophenyl-4'-biguanylphenylsulphone* (XX).—Hydrochloride of 4-nitro-4'-aminodiphenylsulphone (15.8 g.) and dicyandiamide (8.4 g.) were heated together in an oil-bath at 150° for 10 hours. On cooling, it was leached with ammonium hydroxide and filtered. The product was freed from the reactants by successively boiling with water and alcohol. Being insoluble in all the common organic solvents it could not be crystallised. It decomposed above 300°, yield 8.8 g.

Melting points and analytical data of the compounds are tabulated below.

TABLE I

'Act' denotes acetaminophenyl ; 'Am.' aminophenyl and 'S', sulphone.

No.	Compound.	M. p.	Formula,	Nitrogen per cent	
				Found.	Calc.
I	4-act. propyl-S.	135°	C <sub>11</sub> H <sub>15</sub> O <sub>3</sub> NS	5.80	5.80
II.	4-Am. propyl-S.	99°	C <sub>9</sub> H <sub>13</sub> O <sub>3</sub> NS	7.00	7.04
III.	4-Act. butyl-S.	112°	C <sub>13</sub> H <sub>17</sub> O <sub>3</sub> NS	5.48	5.50
IV.	4-Am. butyl-S.	93°	C <sub>10</sub> H <sub>15</sub> O <sub>2</sub> NS	6.76	6.60
V.	4-Act. isoamyl-S.	108°	C <sub>13</sub> H <sub>20</sub> O <sub>3</sub> NS	5.32	5.18
VI.	4-Am. isoamyl-S.	114°	C <sub>11</sub> H <sub>19</sub> O <sub>3</sub> NS	5.97	6.14
VII.	4-Act. heptyl-S.	99°	O <sub>15</sub> H <sub>23</sub> O <sub>3</sub> NS	4.63	4.71
VIII.	4-Am. heptyl-S.	97°	C <sub>13</sub> H <sub>21</sub> O <sub>2</sub> NS	5.56	5.50
IX.	4-Act. acetyl-S.	115°	C <sub>11</sub> H <sub>13</sub> O <sub>4</sub> NS	5.56	5.50
X.	4-Am. acetyl-S.	135°	C <sub>9</sub> H <sub>11</sub> O <sub>3</sub> NS	6.71	6.57
XI.	4-Act. picryl-S.	240° (decomp.)	C <sub>14</sub> H <sub>10</sub> O <sub>9</sub> N <sub>4</sub> S	13.72	13.66
XII	4-Am. picryl-S.	165° (decomp.)	O <sub>12</sub> H <sub>8</sub> O <sub>8</sub> N <sub>4</sub> S	15.10	15.21
XIII.	4-Act. β-hydroxyethyl-S.	195° (decomp.)	C <sub>10</sub> H <sub>15</sub> O <sub>4</sub> NS	5.81	5.75
XIV.	4-Act. 2' : 5'-dihydroxy-phenyl-S.	272°	C <sub>14</sub> H <sub>13</sub> O <sub>5</sub> NS	4.50	4.60
XV.	4-Am. 2' : 5'-dihydroxy-phenyl-S.	177°	C <sub>12</sub> H <sub>11</sub> O <sub>4</sub> NS	5.18	5.28
XVI.	4-Act. 2' : 5'-dihydroxy-3'-isopropyl-6'-methyl-phenyl-S.	244°	C <sub>18</sub> H <sub>21</sub> O <sub>5</sub> NS	3.79	3.86
XVII.	4-Am. 2' : 5'-dihydroxy-3'-isopropyl-6'-methyl-phenyl-S.	231°	C <sub>16</sub> H <sub>19</sub> O <sub>4</sub> NS	4.29	4.36
XVIII.	4-Act. 4'-nitrobenzyl-S.	270° (decomp.)	C <sub>15</sub> H <sub>14</sub> O <sub>5</sub> N <sub>2</sub> S	8.13	8.38
XIX	4-Nitrophenyl-4'-dicarbethoxymethyl-Am-S.	145° (decomp.)	C <sub>19</sub> H <sub>20</sub> O <sub>8</sub> N <sub>2</sub> S	6.4	6.43
XX.	4-Nitrophenyl-4'-biguanylphenyl-S.	300° (decomp.)	C <sub>14</sub> H <sub>14</sub> O <sub>4</sub> N <sub>6</sub> S	23.18	23.22

One of the authors (B. C. J.) wishes to express his thanks to the Lady Tata Memorial Trust for the award of a scholarship which enabled him to participate in this research.

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## ISOLATION OF CARDIOTOXIN FROM COBRA VENOM (*NAJA TRIPUDIANS*, MONOCELLATE VARIETY)

BY NIRMAL KUMAR SARKAR

Isolation of an active principle "Cardiotoxin" from cobra venom (*Naja tripudians*) has been made by fractional precipitation method using different electrolytes such as  $\text{Na}_2\text{SO}_4$ ,  $\text{NaCl}$  as precipitants and it has been found to be, weight by weight, 15 times more toxic, when compared biologically, than crude cobra venom. The isoelectric point and nature of its charge at different  $p_H$  values have been determined by the micro-cataphoretic and transport methods, and they agree fairly well.

During the last fifty years considerable amount of work has been done on the physiological properties of snake venoms, in particular of cobra venom. The different properties of cobra venom such as haemolysis of blood, failure of respiration and circulation etc., have been attributed to the different active constituents present in it; the more important ones isolated so far are haemolysin (*Ann. Biochem. Expt. Med.*, 1944, 4, 45), neurotoxin (*Ind. J. Med. Res.*, 1941, 29, 2) and choline-esterase (*Ann. Biochem. Expt. Med.*, 1944, 4, 78). It has been recently suggested by Sarkar *et al* (*Ind. J. Med. Res.*, 1942, 30, 453) that cobra venom possibly contains some other substance which brings about the stoppage of the heart. It was later on confirmed by the author (unpublished work). Cobra venom therefore contains, besides haemolysin, two other toxic principles. The one responsible for the failure of respiration has been termed as "respiratory toxin" and the other responsible for the cardiac failure has been called "cardiotoxin". An attempt has been made to isolate this active principle called "cardiotoxin" from cobra venom (*Naja tripudians*) in a pure and concentrated form. The method, as developed for its isolation, is described in this communication.

### EXPERIMENTAL

#### *Isolation of Cardiotoxin from Cobra Venom (Naja tripudians Monocellate Variety)*

To a 1% solution of cobra venom\* adjusted at  $p_H$  6.5 (2 g. of cobra venom dissolved in 200 c. c. of distilled water), 44g. of anhydrous sodium sulphate were gradually added with stirring. The whole mixture was kept at  $37^\circ$  for about 30 minutes. The precipitate was filtered off under suction (Whatman filter paper No. 50). The residue was again dissolved in water ( $p_H$  6.5) and the process repeated as before three times. The precipitate, thus obtained, was dissolved in normal saline

\*The venom was extracted from the poison glands of cobra (*Naja tripudians*) and dried in a vacuum desiccator over fused calcium chloride.

(100 c. c.). The  $p_H$  of the solution was brought down to 2.8 and was treated with 17g. of sodium chloride. It was kept at  $37^\circ$  for 30 minutes and filtered. This procedure was repeated once more and the material obtained at this stage was again dissolved in 50 c. c. of normal saline. This solution ( $p_H$  adjusted to 4.2) was further treated with 12 g. of sodium chloride. It was kept at  $37^\circ$  for 30 minutes and filtered. The precipitate obtained was next dissolved in 50 c. c. of redistilled water ( $p_H$  adjusted to 6.0) and the cardiac principle was precipitated by 15 g. of sodium chloride. The solution was kept at  $37^\circ$  for 30 minutes and then filtered. The precipitate obtained at this stage contained not only the active principle but also certain amount of electrolytes, which were removed by dialysis.

*Preparation of Salt-free Cardiotoxin.*—A sheet of cellophane paper, free from pin holes, was tied around a large one-holed cork through which passed a funnel. The cellophane bag with its contents (a solution of cardiotoxin) was suspended in a large beaker of water and the whole arrangement was placed inside a refrigerator maintained at  $7^\circ$  to  $8^\circ$ . The surrounding water was frequently changed to remove the electrolytes which diffused out. The presence of any salt in the surrounding medium was tested from time to time until it was free from any foreign ion. The protein solution was then withdrawn and any undissolved substance was removed by centrifuging. From the clear solution cardiotoxin was precipitated with ethyl alcohol at  $0^\circ$ . The precipitate thus obtained was then centrifuged and repeatedly washed with ice-cold ether. It was then dried over fused calcium chloride in a vacuum desiccator.

This method yielded cardiotoxin, which, weight for weight, was found to be 15 times more toxic than the crude venom, as measured biologically in terms of 'frog unit' \* or 'cat unit' \*\*.

*Estimation of Cardiac Activity.*—The cardiac activity of the cardiotoxin obtained during and after the final stage of purification was measured by \*(i) excised toad's heart method and \*\*(ii) intravenous cat method.

*Estimation of Toxicity.*—To estimate the toxicity of cobra venom or cardiotoxin, pigeons weighing between 300 g. and 310 g. were used. Graded amounts of venom solution or solution of cardiotoxin were administered intramuscularly into the pigeons and the time required for death was noted against each case. The amount of cobra venom which was just sufficient to bring about death of the animal within 6 hours of injection was taken as the 'toxic unit', and the percentage of toxicity of the unknown sample of cardiotoxin was then determined from (i) the amount required to effect death of the pigeon within that period of time and (ii) the amount of cardiotoxin obtained from a known quantity of venom.

\*A 'frog unit' is used here to mean the minimum concentration of the crude venom or cardiotoxin required to bring about a stoppage of perfused toad heart (5 c. c. perfusate being used in each experiment).

\*\*A 'cat unit' is similarly another arbitrary unit of potency which indicates that amount of crude venom or cardiotoxin (in mg/kg. body weight of cat) which will bring about an arrest of the heart beat on intravenous administration into an anaesthetised cat.

*Estimation of Protein.*—Percentage of protein in cobra venom or cardiotoxin was determined by the well known micro-Kjeldahl method.

The non-protein nitrogen (N. P. N.) was determined in the supernatant liquid by the above method after the complete precipitation of the protein by adding equal volumes of a 10% solution of sodium tungstate and  $2/3$  *N*-sulphuric acid. The difference between the total nitrogen (T. N.) and the non-protein nitrogen (N. P. N.) multiplied by the factor 0.2 gave the nitrogen content of the substance and this when further multiplied by a factor 6.25 gave the amount of the protein present in the material.

*Estimation of Haemolysin.*—The amount of haemolysin present in crude venom or cardiotoxin was determined according to the method developed by Slotta *et al.* (*Mem. Inst. Butantan*, 1937, 133).

TABLE I

*Relative percentages of toxicity, protein and haemolysin associated with the cardiotoxin obtained at the different stages of its isolation from cobra venom (Naja tripudians, monocellate variety).*

No.	Precipitate, how obtained.	Toxicity.	Protein.	Haemolysin.	Cardiotoxin.
1.	Crude venom	100 (actual protein content 90.6)	100.0	100	100
2.	Ppt. obtained by dissolving the venom and precipitating at $p_H$ 6.5 with 22% $Na_2SO_4$	40.2	41.5	75	95
3.	Ppt. obtained by dissolving the ppt. (2) and precipitating at $p_H$ 6.5 with 22% $Na_2SO_4$	21.5	32.0	50.8	90
4.	Ppt. obtained by dissolving ppt. (3) and precipitating at $p_H$ 6.5 with 22% $Na_2SO_4$	9.46	21.65	20.2	75
5.	Ppt. obtained by dissolving the precipitate (4) and precipitating at $p_H$ 2.8 with 17% NaCl	5.8	9.26	14.7	60
6.	Ppt. obtained by dissolving the ppt. (5) and precipitating at $p_H$ 2.8 with 17% NaCl	3.85	5.24	9.82	54
7.	Ppt. obtained by dissolving the ppt. (6) and precipitating at $p_H$ 4.2 with 24% NaCl	1.85	3.27	5.46	8
8.	Ppt. obtained by dissolving the ppt. (7) and precipitating at $p_H$ 6.0 with 30% NaCl.	< 0.2	2.42	< 1.0	40

*Isolation of Cardiotoxin from Cobra Venom*  
(*Naja tripudians Binocellate Variety*)

The above method was also employed to separate the cardiotoxin from the other constituents of venom extracted from the binocellate variety of *Naja tripudians*. By adopting the above procedure, 72 mg. of cardiotoxin were obtained from 3 g. of cobra venom (binocellate variety), and its activity was found to be equivalent to 1.2 g. of cobra venom. Therefore weight for weight this purified cardiotoxin is also 15 times more toxic than the venom.

A comparative study of purification of cardiotoxin from different venoms has been made. The results are shown in Table II.

TABLE II

Substance.	Relative percentage of		Purity.
	Protein.	Activity.	
<i>Naja tripudians</i> venom (monocellate variety)	90.6	100	—
<i>Naja tripudians</i> venom (binocellate variety)	90.2	100	—
Cardiotoxin isolated from monocellate variety	2.42	40.0	15
Cardiotoxin isolated from binocellate variety	2.44	40.2	14.8

*Determination of the Isoelectric Point of Cardiotoxin*

Of the different properties which characterise a protein, the isoelectric point is of fundamental importance. Perrin and Hardy (*Z. physiol. Chem.*, 1900, 33, 385; *J. Physiol.*, 1905, 33, 351) have observed that proteins behave as ions and migrate either to the anode or to the cathode in a solution when subjected to an electrical field according to the nature of the electrical charge they carry.

The isoelectric point of proteins (the condition of no migration) is said to be the condition of minimum properties such as (i) minimum charge, (ii) minimum viscosity, (iii) minimum conductivity, (iv) minimum osmotic pressure, (v) minimum hydration, etc. and a determination of the isoelectric point is possible from a comparative study of any one of the properties mentioned above, provided it is suitable for the protein in question.

Buffer index method can also be used to determine the isoelectric point of a protein. The essence of the method is to dissolve the protein in buffers, having different  $p_H$  values; the point at which the shift of  $p_H$  will be the minimum is considered as the isoelectric point of the protein concerned.

Isoelectric point of a protein can also be determined by micro-cataphoretic and moving boundary methods. The microscopic method is only suitable for larger particles which are visible under the microscope or ultra-microscope, while the moving boundary method can be conveniently used for substances in the dissolved state and as such can be employed in the study of protein solutions.

It is known that when a protein solution is shaken with quartz particles, the particles acquire the charge identical with that of the protein molecule. Loeb (*J. Gen. Physiol.*, 1923, 6, 105) showed that the isoelectric point of gelatine or of egg-albumin, measured either in solution or adsorbed on the surface of quartz particles, gave fairly concordant results. Moyer (*J. Biol. Chem.*, 1937, 122, 641) showed that the electric mobility of horse serum (pseudoglobulin) adsorbed on collodion particles was the same as the electric mobility of the protein in the dissolved state. The isoelectric point of serum albumin as determined by Abramson (*J. Gen. Physiol.*, 1932, 15, 575) by microcataphoretic method compares favourably well with that of Tiselius (*Nova. acta. reg. Soc. Sci. upsaliensis*, 1933, 7, No. 4) who determined the isoelectric point of the same substance by the moving boundary method.

The nature of the electric charge and migration of the particles of cardiotoxin at different  $p_H$  values have been investigated by the microcataphoretic as well as by the transport method. The experimental procedure is as follows.

*Microcataphoretic Method.*—Electric mobility of microscopically visible quartz particles, covered with a film of adsorbed cardiotoxin, was determined in modified Northrop-Kunitz micro-electrophoresis cells (*J. Gen. Physiol.*, 1925, 8, 729). In general the same concentration of cardiotoxin was used in all experiments with quartz particles. Quartz particles (*J. Gen. Physiol.*, 1929, 12, 169) were washed for days with distilled water after cleaning with concentrated hydrochloric acid. Approximately the same number of quartz particles of the same average size was used throughout. The quartz particles were added to the cardiotoxin solution and they were allowed to remain in contact with the solution for several minutes. Cardiotoxin solutions were made in phosphate and borate buffers between the  $p_H$  6.0 and 7.5 and  $p_H$  8.0 and 9.5 respectively. The specific resistance of each such solution was measured by using a Hartman-Braun Roller conductivity bridge in conjunction with an L & N Curtis coil resistance set, the alternating current being derived by means of a Vreeland oscillator. The potential gradient was calculated with the help of Ohm's law. The  $p_H$  of the solution was determined by indicator and E. M. F. methods.

TABLE III

*Cataphoretic velocities of cardiotoxin*

$p_H$ .	O.V.	$p_H$ .	O.V.
6.0	+0.876	8.0	+0.25
6.5	+0.700	8.5	-0.125
7.0	+0.450	9.0	-0.350
7.5	+0.266	9.5	-0.525

*Transport Method.*—The apparatus consists of a U-tube, each limb of which is provided with a stop-cock exactly at the same height. Into the bottom of the U-tube, is sealed a narrow delivery tube provided with a stop-cock and



a funnel at its extremity. This tube is bent round, so as to run up behind the limbs and to bring the funnel to the same height as the top of the U-tube.

A 0.5% solution of cardiotoxin in Ringer, adjusted at different  $p_H$  values was used in these experiments. The U-tube was partially filled with the same solvent in which cardiotoxin was dissolved. The stop-cocks in the two side limbs were kept open and two platinised platinum electrodes were introduced into these limbs so that they remained above the level of the stop-cocks. The cardiotoxin solution was then poured into the funnel at the extremity of the delivery tube with the stop-cock closed and the whole apparatus was then placed inside a thermostat adjusted at  $35^\circ \pm 0.1$ .

The solution from the funnel was now allowed to flow slowly into the U-tube by partially opening the stop-cock in the delivery tube till the cardiotoxin solution reached the stop-cocks in the limbs of the U-tube. This required about 15 to 20 minutes: times in the course of which the solution inside the U-tube acquired the temperature of the thermostat ( $35^\circ$ ). The stop-cocks in the side tubes were then closed and volumes of the solvent were then poured into the side tubes. The stop-cocks were then opened, and the electrical connection was made and the current allowed to pass for a definite period of time, at the expiry of which the stop-cocks in the limbs of the U-tube closed and the protein solution, which migrated, was taken out for quantitative measurement of the cardiac activity.

TABLE IV

*Electrophoresis of cardiotoxin solution in a U-tube.*

$p_H$	Units of cardiotoxin at the	
	anode.	cathode.
8.00	1.02 frog units	9.6 frog units
8.10	<1	4.28
8.15	<1	1.54
8.20	Do	<1
8.25	1.25	Do
8.30	2.56	Do

The value of the isoelectric point of cardiotoxin as determined by these methods agree fairly well and is in the neighbourhood of  $p_H$  8.2.

The author's best thanks are due to Dr B. N. Ghosh and Mr. S. R. Maitra for their valuable suggestions and interest taken during the progress of the work.

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# APPLICATION OF HAMMICK AND ANDREW'S EQUATION TO TERNARY MIXTURES. PART III.

BY S. O. SHUKLA AND W. V. BHAGWAT

Hammick and Andrew's equation is applicable to ternary mixtures of glucose, urea and acetamide in water. The values are compared with those obtained in aqueous solution and not with the calculated values. It is observed that for binary mixtures the values obtained for solids are generally much lower than those obtained by calculations.

For determining the parachors of binary and ternary mixtures the formulae

$$P_m = (1-x) P_p + x P_x \text{ and}$$

$$P_m = (1-x-y) P_p + x P_x + y P_y$$

respectively are employed; where  $P_m$ ,  $P_x$ ,  $P_y$ ,  $P_p$  and  $x$  have their usual significance.

In previous papers (*J. Indian Chem. Soc.*, 1944, 21, 179; 1945, 22, 311) it was shown that the mixture law of determining parachor was applicable to ternary mixtures. The work has been extended in this paper.

## Parachor of Glucose

TABLE I

4.9043 G. of glucose dissolved in 14.7623 g. of water. $x$ (glucose) = 0.0321; $1-x$ (water) = 0.9679; $M_m = 23.21$ .					3.5920 G. of glucose dissolved in 14.8654 g. of water. $x = 0.0235$ ; $1-x$ (water) = 0.9765; $M_m = 21.82$ .				
Temp.	$d$ .	$r$ .	$P_m$ .	$P_x$ .	$d$ .	$r$ .	$P_m$ .	$P_x$ .	
26°	1.100	73.57	61.8	347.0	1.078	71.76	59.2	344.2	
30	1.097	72.44	61.72	344.6	1.071	70.99	59.15	342.0	
40	1.093	71.78	61.81	347.3	1.067	69.98	59.14	341.7	
50	1.090	70.79	61.77	346.1	1.064	69.18	59.14	341.7	
Calc. value = 377.2									
5.5812 G. of glucose dissolved in 14.9040 g. of water. $x = 0.0361$ ; $1-x =$ 0.9639; $M_m = 23.84$ .					2.8293 G. of glucose dissolved in 14.295 g. of water. $x = 0.0198$ ; $1-x =$ 0.9807; $M_m = 21.14$ .				
26°	1.110	73.75	62.94	346.9	1.063	71.86	57.91	340.9	
30	1.107	72.44	62.85	343.4	1.061	71.29	57.89	339.9	
40	1.103	71.61	62.88	344.3	1.058	70.31	57.86	338.3	
50	1.100	70.63	62.84	343.2	1.054	69.18	57.84	337.8	

## Parachor of Urea

There seems to be some discrepancy in the values recorded by us in our previous paper for the parachor of urea (*J. Indian Chem. Soc.*, 1944, 21 179). The revised results are recorded below.

TABLE II

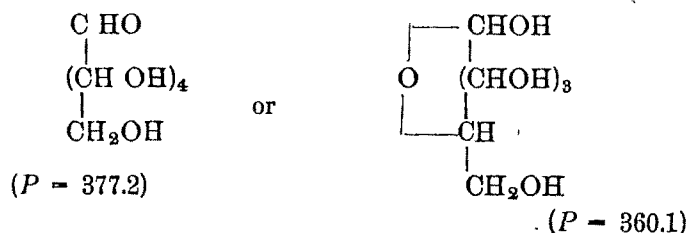
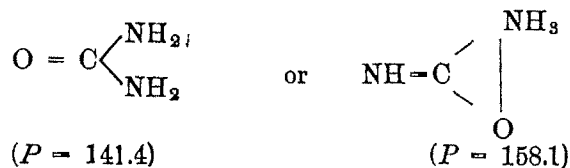
5.4378 G. of urea dissolved in 14.8954g. of water. $x$ (urea) = 0.936; $1-x$ = 0.9014; $M_m$ = 22.07.					7.0292 G. of urea dissolved in 14.7088 g. of water. $x$ = 0.1253; $1-x$ = 0.8747; $M_m$ = 23.27.			
Temp.	$d$ .	$r$ .	$P_m$ .	$P_x$ .	$d$ .	$r$ .	$P_m$ .	$P_x$ .
26°	1.070	72.04	60.09	130.9	1.087	71.69	62.15	130.6
30	1.067	70.79	59.99	129.9	1.075	70.70	62.2	131.0
40	1.063	69.98	60.05	130.5	1.082	70.15	62.24	131.3
50	1.057	68.87	60.15	131.5	1.078	68.87	62.18	130.8

Calc. value = 141.2

8.7788 G. of urea dissolved in 15.0083 g of water. $x$ = 0.1493; $1-x$ = 0.8507; $M_m$ = 24.27				
Temp.	$d$ .	$r$ .	$P_m$ .	$P_x$ .
26°	1.101	71.39	64.6	130.8
30	1.099	70.47	64.01	130.5
40	1.091	69.18	63.96	130.1
50	1.090	67.76	63.84	129.1

The work of Hammick and Andrew (*J. Chem. Soc.*, 1929, 754) for binary mixtures includes only liquid-liquid mixtures, where the agreement between the calculated and the observed values is excellent. Our work with solid-liquid mixtures (*loc. cit.*) shows that the values obtained in solution for solids (non electrolytes) are generally smaller than the calculated values. These observations for solid-liquid system are similar to those of Hammick and Andrew (*J. Chem. Soc.*, 1934, 33) in case of tetranitromethane in benzene and to those of Ray (*J. Indian Chem. Soc.*, 1934, 11, 845; 1935 12, 407) in case of fructose in various solvents. In applying therefore the equation for ternary mixture, we have not used the calculated values, but the actual values obtained for these solids in water. The agreement between these results and those obtained by ternary expression is excellent. This will be clear from the following results.

Urea and glucose may have the following structures.



The values obtained in each case are lower than the corresponding set of values given by the above structures. Clearly the observed values approach that structure whose calculated values are lower. But since the values in water are in general smaller, it will not be justified to say that the structure of glucose or urea corresponds to that formula which gives smaller value on calculations.

TABLE III

*Glucose, acetamide and water system.*

2.470 G. of glucose and 7.2052 g. of acetamide dissolved in 7.3983 g. of water. $x$ (glucose) = 0.0230; $y$ (acetamide) = 0.2233; $1-x-y$ (water) = 0.7537; $M_m = 81.20$ . Parachor of water as determined = 52.34; parachor of acetamide = 135.					Glucose (2.6758g.) and acetamide (5.3210g.) dissolved in 7.4562 g. of water. $x$ (glucose) = 0.0235; $y$ (acetamide) = 0.1735 $1-x-y$ (water) = 0.7980; $M_m = 29.76$ .				
Temp.	$d.$	$r.$	$P_m.$	$P_x.$	$d.$	$r.$	$P_m.$	$P_x.$	
25°	1.087	53.2	77.54	346.7	1.092	57.48	75.06	346.4	
30	1.085	52.48	77.39	340.2	1.090	56.62	75.0	344.0	
40	1.081	52.0	77.52	345.8	1.087	55.34	75.11	343.5	
50	1.078	51.29	77.45	342.8	1.083	53.7	75.08	347.0	
4.9380 G. of glucose and 10.5462 g. of acetamide dissolved in 15.0038 g. of water. $x$ (glucose) = 0.02616; $y$ (acetamide) = 0.1719; $1-x-y$ (water) = 0.80194; $M_m = 29.30$ .					5.3212 G. of acetamide and 1.7916 g. of glucose dissolved in 7.8084 g. of water. $x$ (acetamide) = 0.1701; $y$ (glucose) = 0.0189; $1-x-y$ (water) = 0.8110; $M_m = 28.24$ .				
25°	1.087	56.86	74.11	340.2	1.071	56.76	72.28	136.2	
30°	1.085	56.23	73.93	335.2	1.068	55.95	72.11	135.8	
40°	1.082	55.72	73.82	331.0	1.065	54.95	72.11	135.8	
50°	1.078	54.95	73.99	337.5	1.060	53.83	72.14	136.0	
7.9932 G. of acetamide and 1.7974 g. of glucose dissolved in 7.4424 g. of water.					$x$ (acetamide) = 0.2395; $y$ (glucose) = 0.0177; $1-x-y$ (water) = 0.7428; $M_m = 30.97$				
Temp.	$d.$	$r.$	$P_m.$	$P_x.$					
26°	1.069		51.88		77.8		136.6		
30°	1.066		51.11		77.69		136.1		
40°	1.062		50.12		77.43		135.0		
50°	1.058		49.2		77.54		135.5		

TABLE IV

*Urea, glucose and water system.*

5.4694 G. of urea and 4.8648 g. of glucose dissolved in 14.9054 g. of water. $x$ (urea) = 0.09628; $y$ (glucose) = 0.02858; $1-x-y$ (water) = 0.87519; $M_m = 26.68$ .					7.0774 G. of urea and 4.9294 g. of glucose dissolved in 14.9632 g. of water. $x$ (urea) = 0.1207; $y$ (glucose) = 0.02805; $1-x-y$ (water) = 0.8513; $M_m = 27.61$ .				
Temp.	$d.$	$r.$	$P_m.$	$P_x.$	$d.$	$r.$	$P_m.$	$P_x.$	
25°	1.140	72.93	68.39	131.6	1.149	72.71	70.18	132.7	
30	1.138	72.11	68.32	130.9	1.147	71.78	70.08	130.8	
40	1.135	71.45	68.34	131.1	1.144	70.79	70.01	130.2	
50	1.131	70.79	68.40	132.0	1.141	70.15	70.03	130.4	

TABLE IV (contd.)

7.7760 G. of urea and 4.9796 g. of glucose dissolved  
in 13.9140 g. of water.  $x$  (urea)=0.1392 ;  
 $y$  (glucose)=0.0297 ;  $1-x-y$  (water)  
=0.8311 ;  $M_m=28.65$ .

	Temp.	$d$ .	$P_m$ .	$P_x$ .
25°	1.159	74.01	72.51	134.3
30	1.158	72.95	72.43	133.0
40	1.154	71.78	72.28	132.7
50	1.150	70.79	72.28	132.7

7.1090 G. of urea and 3.5556 g. of glucose dissolved  
in 14.9388 g. of water.  $x$  (urea)=0.1224 ;  
 $y$  (glucose)=0.0203 ;  $1-x-y$  (water)  
=0.8573 ;  $M_m=28.44$ .

26°	1.132	71.47	67.89	130.5
30	1.129	70.47	67.87	130.3
40	1.125	69.18	67.79	129.5
50	1.120	67.76	67.74	129.2

4.2864 G. of urea and 3.5926 g. of glucose dissolved  
in 14.8706 g. of water.  $x$  (urea)=0.0778 ;  
 $y$  (glucose)=0.0216 ;  $y=0.0216$  ;  $1-x-y$   
(water)=0.9006 ;  $M_m=24.79$ .

26°	1.116	71.79	64.54	127.3
30	1.114	70.15	64.42	125.8
40	1.111	69.18	64.36	125.0
50	1.107	67.92	64.31	124.4

4.2696 G. of urea and 4.8738 g. of glucose  
dissolved in 14.9166 g. of water.

$x$  (urea)=0.7666 ;  $y$  (glucose)=0.02915 ;  
 $1-x-y$  (water)=0.89416 ;  $M_m=25.99$ .

	Temp.	$d$ .	$P_m$ .	$P_x$ .
	1.133	72.98	66.89	129.8
	1.130	72.11	66.86	129.4
	1.127	71.29	66.76	128.1
	1.123	70.15	66.83	129.0

8.7286 G. of urea and 3.5802 g. of glucose  
dissolved in 14.9078 g. of water.  $x$  (urea)  
=0.1463 ;  $y$  (glucose)=0.0200 ;  $1-x-y$   
(water)=0.8337 ;  $M_m=27.39$

	1.144	73.18	70.01	132.8
	1.142	72.11	69.88	131.9
	1.138	70.79	69.82	131.5
	1.133	69.34	69.76	131.1

5.4532 G. of urea and 3.5946 g. of glucose  
dissolved in 14.9868 g. of water.  $x$  (urea)  
=0.0963 ;  $y$  (glucose)=0.0211 ;  $1-x-y$   
(water)=0.8826 ;  $M_m=25.47$ .

	1.122	72.4	66.21	131.8
	1.120	69.5	66.66	126.1
	1.117	68.55	65.63	125.8
	1.112	67.61	65.67	126.2

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# APPLICATION OF HAMMICK AND ANDREWS EQUATION TO TERNARY MIXTURES. PART IV.

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Ternary systems containing all liquids, such as ethyl acetate, benzene, carbon tetrachloride and toluene have been investigated and Hammick and Andrew's mixture law has been found applicable. Since for binary mixtures of these liquids the calculated and the observed values agree, the same is found to be true in ternary mixtures of these liquids.

In previous papers (*J. Indian Chem. Soc.*, 1944, 21, 179, 1945, 22, 311 ; 1947, 24, 231) it was shown that the expression,

$$P_m = (1-x-y) P_p + xP_x + yP_y$$

is applicable to ternary mixtures containing two solids and the observed results do not agree with the calculated ones but with those obtained in solutions of binary mixtures. In this paper the work is extended to ternary mixtures consisting of liquids only. At first the parachors of pure liquids individually have been determined and the results agree with the calculated values.

TABLE I

Liquid.	<i>d.</i>	<i>r.</i>	<i>P</i> <sub>obs.</sub>	Liquid.	<i>d.</i>	<i>r.</i>	<i>P</i> <sub>obs.</sub>
Benzene	0.8661	27.8	206.6	Toluene	0.8558	27.52	246.1
Ethyl acetate	0.8907	22.68	215.7	Ethyl acetate	1.578	27.19	222.3

## *Ethyl Acetate, Toluene and Benzene System*

In the following tables parachor of ethyl acetate has been calculated which in the pure liquid state comes out to be 215.7.

TABLE II

4.8310 G. of ethyl acetate and 5.0836 g of toluene dissolved in 4.1858 g. of benzene. *x* (ethyl acetate)=0.3114; *y* (toluene)=0.3493; 1-*x*-*y* (benzene)=0.3393; *M*<sub>m</sub>=86.06.

3.5294 G. of ethyl acetate & 4.7076 g of toluene dissolved in 6.644 g. of benzene. *x* (ethyl acetate)=0.4824; *y* (toluene)=0.2273; 1-*x*-*y* (benzene)=0.2903; *M*<sub>m</sub>=84.36.

Temp.	<i>d.</i>	<i>r.</i>	<i>P</i> <sub>m.</sub>	<i>P</i> <sub>x.</sub>	<i>d.</i>	<i>r.</i>	<i>P</i> <sub>m.</sub>	<i>P</i> <sub>x.</sub>
26°	0.8698	25.87	223.2	215.6	0.8677	26.87	221.4	218.6
30	0.8680	25.67	223.2	215.6	0.8645	26.42	221.3	218.2
35	0.8646	25.12	222.8	214.8	0.8600	25.70	220.9	217.6
40	0.8601	24.66	223.0	214.9	0.8550	25.12	220.9	217.6

6.8574 G. of ethyl acetate and 3.4918 g. of toluene dissolved in 3.4464 g. of benzene. *x* (ethyl acetate)=0.4368; *y* (toluene)=0.2368; 1-*x*-*y* (benzene)=0.2764; *M*<sub>m</sub>=86.22.

4.8938 G. of ethyl acetate and 6.5856 g. of toluene dissolved in 4.0742 g. of benzene. *x* (ethyl acetate)=0.2874; *y* (toluene)=0.4118; 1-*x*-*y* (benzene)=0.9008; *M*<sub>m</sub>=86.71.

26°	0.8735	25.0	220.8	216.7	0.8675	25.8	225.3	215.0
30	0.8701	24.55	220.6	216.1	0.8641	25.35	225.2	214.7
35	0.8655	24.04	220.6	216.1	0.8602	25.0	225.4	215.4
40	0.8608	23.28	220.2	215.5	0.8566	24.55	225.3	215.0

TABLE II (contd.)

4.2868 G. of ethyl acetate and 4.5610 g. of toluene dissolved in 2.0976 g. of benzene. $x$ (ethyl acetate)=0.3636; $y$ (toluene)=0.3741; $1-x-y$ (benzene)=0.2623; $M_m=88.88$ .					2.7894 G. of ethyl acetate and 4.5938 g. of toluene dissolved in 4.1746 g. of benzene. $x$ (ethyl acetate)=0.2346; $y$ (toluene)=0.3693; $1-x-y$ (benzene)=0.3961; $M_m=85.55$ .			
Temp.	$d.$	$r.$	$P_m.$	$P_x.$	$d.$	$r.$	$P_m.$	$P_x.$
26°	0.8714	25.69	224.5	215.2	0.8673	26.48	223.9	218.1
30	0.8680	25.18	224.2	214.4	0.8640	25.94	223.6	216.8
35	0.8641	24.66	224.1	214.1	0.8601	25.41	223.3	215.5
40	0.8592	24.21	224.3	214.6	0.8562	24.83	222.9	213.9

TABLE III

*Ethyl acetate, benzene and carbon tetrachloride system.*

4.4536 G. of ethyl acetate & 4.3862 g. of benzene dissolved in 8.2790 g. of $CCl_4$ . $x$ ( $CCl_4$ )=0.3115; $y$ (ethyl acetate)=0.3437; $1-x-y$ (benzene)=0.3448; $M_m=108.9$ .					10.3278 G. of $CCl_4$ and 4.4578 g. of ethyl acetate dissolved in 4.1476 g. of benzene. $x$ ( $CCl_4$ )=0.3924; $y$ (ethyl acetate)=0.2962; $1-x-y$ (benzene)=0.3114; $M_m=110.8$ .			
Temp.	$d.$	$r.$	$P_m.$	$P_x.$	$d.$	$r.$	$P_m.$	$P_x.$
27°	1.117	25.74	215.6	224.6	1.156	26.1	216.6	225.2
30	1.114	25.35	215.4	223.6	1.154	25.7	216.1	223.0
35	1.108	24.89	215.6	224.6	1.148	25.23	216.3	224.4
40	1.108	24.32	215.3	223.3	1.140	24.72	216.6	225.2
7.5588 G. of $CCl_4$ and 4.8070 g. of ethyl acetate dissolved in 7.0302 g. of benzene. $x$ ( $CCl_4$ )=0.2539; $y$ (ethyl acetate)=0.2812; $1-x-y$ (benzene)=0.4649; $M_m=100.1$ .					7.8124 G. of $CCl_4$ and 6.8974 g. of ethyl acetate dissolved in 4.0680 g. of benzene. $x$ ( $CCl_4$ )=0.2776; $y$ (ethyl acetate)=0.4417; $1-x-y$ (benzene)=0.2807; $M_m=102.4$ .			
27°	1.058	26.02	213.6	224.0	1.078	26.17	214.8	221.6
30	1.055	25.59	213.3	222.9	1.076	25.7	214.2	219.6
35	1.049	25.12	213.6	224.0	1.070	25.18	214.8	221.5
40	1.043	24.6	213.7	224.0	1.062	24.55	214.6	221.5
13.7202 G. of $CCl_4$ and 3.6604 g. of ethyl acetate dissolved in 3.6382 g. of benzene. $x$ ( $CCl_4$ )=0.5060; $y$ (ethyl acetate)=0.2294; $1-x-y$ (benzene)=0.2646; $M_m=119.3$ .								
Temp.	$d.$	$r.$	$P_m.$	$P_x.$				
27°	1.235	25.84	217.8	224.4				
30	1.232	25.47	217.5	224.0				
35	1.226	24.66	216.8	222.6				
40	1.218	24.15	217.2	223.2				

## STUDIES ON RANCIDITY OF BUTTER-FAT

BY S. MUKHERJEE AND M. GOSWAMI

Development of rancidity on butter-fat on storage with different chemicals has been studied. Effect of hydrogen passed into the butter-fat at room temperature has been investigated. The dissolved hydrogen has been found to stop hydrolytic rancidity of butter-fat for a period of 5 months and to retard oxidative rancidity to a very great extent.

The prevention of rancidity in edible fats is a problem of vast importance which has not yet been solved. The reasons assigned for deterioration of fats are generally oxygen, light, temperature, moisture, micro-organisms, materials of the container and above all, the unsaturated glycerides and the lower glycerides which on decomposition give the rancid odour. The mechanism of the decomposition has been the subject of various communications but it cannot be said that it has been as yet cleared. The only thing that has been achieved is that with addition of certain substances, both natural and synthetic, called antioxidants, it has been possible to retard the decomposition for a certain period. The uses of the synthetic antioxidants are limited in case of edible oils, as many of them are toxic. Lea (*J. Soc. Chem. Ind.*, 1936, 55, 293T) examined and proposed for this purpose, citric and allied type of acids and several amino-acids. Natural antioxidants, prepared from vegetable oils, have been also used by Matill and co-workers (*J. Amer. Chem. Soc.*, 1936, 58, 2204). Gossypol, among the antioxidants was shown by Matill to be much superior. Coe (*Oil & Soap*, 1930, 15, 230) claimed catalase preparations to be much more effective as antioxidants than the pyrogallol derivatives. Numerous works have been done on the use of synthetic antioxidants for retarding rancidity, and for edible fats, especially butter-fat, the use of ethyl gallate (0.005 to 0.02%) has been recommended by Lea. Recently Banerjee has shown that Kamala dye (*Curr. Sci.*, 1939, 8, 559) is an effective antioxidant for butter-fat. Davis (*J. Indian Chem. Soc. Ind. & News Ed.*, 1940, 3, 124) has shown the efficacy of cereal flour paste.

The term rancidity has been for a long time used to represent two entirely different changes which take place in fats and oils: (i) the hydrolysis of the glycerides with liberation of free fatty acid, and (ii) the oxidation of fats and oils containing unsaturated acids resulting in the formation of aldehydes, ketones, acids of lower molecular weights and organic peroxides. In general, the two phenomena of hydrolytic and oxidative rancidity proceed simultaneously, so that practically no sharp line of demarcation can be drawn from the practical point of view.



In the process of hydrolytic rancidity there is always an increase in titratable acidity, and determination of acid value is adopted to follow the course of hydrolysis of glycerides. The most practical assessment of oxidative rancidity is by organoleptic tests, based on taste reports. Whilst development of flavours is generally accepted as the ultimate criterion of stability, organoleptic tests are less easy to control than tests of a more definitely chemical nature. The course of oxidative rancidity is usually therefore followed by determination of Kries number and the peroxide value, based respectively on the presence of epihydrin aldehyde  $\begin{array}{c} | - O - | \\ (CH_2 - CH \cdot CHO) \end{array}$  and organic peroxides in fats; the latter is regarded as the most suitable quantitative measure of this type of rancidity though the Kries number, which is extremely useful for qualitative purposes, has also been regarded as semi-quantitative.

### EXPERIMENTAL

The Kries number was determined by the method of Walters, Muers and Anderson (*J. Soc. Chem. Ind.*, 1938, 57, 53r) with a little modification as follows: 3 ml. of melted fat were weighed in a test-tube and diluted to 5 c.c. with amyl acetate to which was added 1 ml. of a 0.5% solution of phloroglucinol in amyl acetate and 2 ml. of trichloroacetic acid solution in amyl acetate ( $x$  g./0.382  $x$  ml.). The resultant mixture was stirred for 3 to 4 seconds by bubbling a stream of air and the test-tube then warmed in a bath at 45° for exactly 15 minutes. The mixture was then diluted with 8 c.c. of a mixture of amyl acetate and alcohol (1 : 1) and colour matched in a Lovibond tintometer. The Kries number (T) is given by the following expression,

$$T = \frac{R}{lc}$$

where R = reading in the Lovibond tintometer;  $l$  = length of the cell,  $c$  = conc. of the oil in total solution in g./c.c.

The addition of a mixture of alcohol and amyl acetate (1 : 1) instead of amyl acetate in diluting the mixture has the advantage that it stabilises the colour for about 10 minutes, which otherwise begins to decompose gradually in the reaction mixture.

The peroxide value was estimated by the modified Wheeler and Paschke method (*Oil & Soap*, 1944, 21, 33) in which the reaction was carried out in an atmosphere of CO<sub>2</sub>. The peroxide value is expressed as the number of c.c. of N/200- thio per g. of the sample.

This paper has mainly been devoted to the study of the development of rancidity on butter-fat on storage with different chemicals. In the first set of experiments the fat was kept both in presence and absence of moisture and in presence of casein and lactose (1% each). The effect of vanillin (0.05%) and that of passing hydrogen gas at room temperature was also studied. These results are given in Tables IA and IB.

TABLE IA

*Acid, Kries and peroxide values of butter-fat stored under different conditions.*

Description of samples	Initial value.	In presence of moisture.				
		After 40 days.	After 60 days.	After 90 days.	After 120 days.	After 150 days.
	A.V. K.N. P.V.	A.V. K.N. P.V.	A.V. K.N. P.V.	A.V. K.N. P.V.	A.V. K.N. P.V.	A.V. K.N. P.V.
1. Air only	150 0.2 0.0	1.83 2.5 0.25	1.93 2.9 0.40	2.05 3.3 0.9	2.25 4.0 1.4	3.0 6.4 1.9
2. " + lactose (1%) "	" "	1.70 2.4 0.0	1.79 2.8 0.05	1.89 3.1 0.5	2.0 3.1 0.8	2.6 5.3 1.0
3. " + casein (1%) "	" "	1.80 3.0 0.0	1.90 2.9 0.10	1.97 3.3 0.6	2.08 3.9 0.95	2.8 5.8 1.15
4. " + Vanillin(0.05%) "	" "	3.6 2.3 0.0	3.65 2.6 0.20	3.95 2.6 0.3	4.3 2.7 0.55	4.8 4.17 1.0
5. " + H <sub>2</sub> gas passed for 4 hrs. at 30°	" "	1.54 2.3 0.0	1.63 2.6 0.05	1.70 2.5 0.35	1.78 2.6 0.45	2.0 4.5 0.8

TABLE IB

Description of samples.	Initial value.	In absence of moisture.				
		After 40 days.	After 60 days.	After 90 days.	After 120 days.	After 150 days.
	A.V. K.N. P.V.	A.V. K.N. P.V.	A.V. K.N. P.V.	A.V. K.N. P.V.	A.V. K.N. P.V.	A.V. K.N. P.V.
1. Air only	150 0.2 0.0	1.80 1.10 0.0	1.84 1.6 0.15	1.89 2.2 0.4	1.93 2.5 0.7	2.15 4.8 0.95
2. " + lactose (1%) "	" "	1.75 1.14 0.0	1.76 2.0 0.0	1.82 2.6 0.10	1.88 2.8 0.25	1.97 4.5 0.5
3. " + Casein (1%) "	" "	1.80 1.5 0.0	1.85 2.1 0.1	1.89 2.9 0.15	1.98 2.9 0.4	2.1 4.9 0.75
4. " + Vanillin(.05%) "	" "	3.3 1.0 0.0	3.9 2.2 0.05	4.4 2.5 0.10	5.2 2.6 0.3	6.6 4.5 0.50

From above, it appears that (a) the fat keeps better in absence of moisture ;  
 (b) casein does not appear to facilitate the keeping power of fat ; (c) milk sugar both

in absence and presence of moisture retards rancidity of butter-fat; (d) the behaviour of vanillin is somewhat curious: whilst it increases the acidity of the fat to a much greater extent than all the substances in the table, it suppresses the figure for the Kries number and peroxide value to a much greater extent *i.e.* it probably retards formation of Kries active substance and organic peroxides, and lastly (e) hydrogen even in presence of moisture seems to be the best retarder of rancidity with respect to both hydrolytic and oxidative rancidity.

In the light of conclusion (a) above, it therefore seemed plausible to carry out the subsequent experiments with completely dry fats. But, since the fats of commerce are invariably associated with a certain amount of moisture, the percentage widely varying, and since majority of foods contains fat in an aqueous phase, the study of the problem of rancidity with anhydrous fats will be of little use from a practical standpoint. Hence, the subsequent storage experiments were all carried out in presence of moisture, after having first ascertained that moisture accelerated the hydrolytic decomposition of glycerides of fatty acids.

Unsaturation in fats has always been a factor in the process of oxidative rancidity in fats and it is well known that reduction of unsaturation by hydrogenation produces fats that keep much better than the mother oils. Selective nature of hydrogenation is well known, and many experimenters have observed that by hydrogenation up to the oleic acid or even to the linoleic acid stage, fats can be obtained with much increased keeping qualities. The experiment No. 5 in Table I with hydrogen was carried out with the simple idea that if instead of having the hydrogen in actual combination with the unsaturated fatty acid molecules, it would be possible to retard rancidity by merely having the hydrogen in a state of dissolution. We have already seen how much hydrogen retards the rancidity, both oxidative and hydrolytic.

TABLE II

Description.	<i>Effect of passing hydrogen at diff. temp. for 2 hours.</i>														
	Initial.			After 40 days.			After 60 days.			After 100 days.			After 150 days.		
	A. V.	K. N.	P. V.	A. V.	K. N.	P. V.	A. V.	K. N.	P. V.	A. V.	K. N.	P. V.	A. V.	K. N.	P. V.
1. H <sub>2</sub> passed at 30°	0.45	0.4	0.0	0.743	16.4	0.0	0.781	1.88	0.15	0.882	2.2	0.42	0.912	2.8	0.454
2. H <sub>2</sub> passed at 40°	"	"	"	0.739	1.52	0.0	0.749	1.62	0.15	0.784	2.0	0.41	0.899	2.61	0.455
3. H <sub>2</sub> passed at 50°	"	"	"	0.504	1.42	0.0	0.512	1.50	0.05	0.537	1.9	0.25	0.589	2.0	0.262
4. H <sub>2</sub> passed at 60°	"	"	"	0.470	1.30	0.0	0.484	1.42	0.0	0.502	1.8	0.15	0.545	2.0	0.208
5. H <sub>2</sub> passed at 70°	"	"	"	0.672	1.55	0.0	0.689	1.81	0.0	0.733	2.1	0.32	0.802	2.4	0.419
6. H <sub>2</sub> passed at 80°	"	"	"	0.674	1.55	0.0	0.697	1.82	0.15	0.766	2.1	0.39	0.846	2.4	0.426
7. H <sub>2</sub> passed at 90°	"	"	"	0.670	1.60	0.0	0.697	1.86	0.15	0.768	2.2	0.4	0.850	2.6	0.487
8. Control	"	"	"	0.874	2.12	0.20	1.24	2.58	0.48	1.847	2.9	1.0	3.02	4.1	2.85

The next series of experiments were carried out with fats in association with moisture through which hydrogen gas was passed for a period of two hours at temperatures 40°, 50°, 60°, 70°, 80° and 90° with the obvious idea of increasing the solubility of hydrogen in the fat (Grimm, Inter. Conf. Bituminous Coal, 1931, II, 49).

The experimental results are given in Table II. It may be seen that up to 40 days there is no rise in peroxide value at any of the temperatures but after that it gradually increases and it is minimum at 60°, above which it rises. Kries number and acid value after 40 days are minimum at 60°, and with storage in general they gradually increase but nevertheless they are minimum at the said temperature even after a period of 150 days. When compared with the control sample it would thus appear that hydrogen has a retarding effect both as regards Kries number and peroxide value.

Further experiments with hydrogen was carried out to observe the effect of storage with this gas under a positive pressure. The experiments were carried out at 30° 50° and 70°, hydrogen being passed for 2 hours and then the samples stored under pressure in an atmosphere of hydrogen. The results are given in Table III and it would be seen that storage with positive pressure does not further improve the result as detailed in Table II. Simultaneously with the

TABLE III

*Effect of passing hydrogen under pressure at diff. temp.*

Description.	Initial.			After 30 days.			After 60 days.			After 90 days.			After 120 days.		
	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.
1. H <sub>2</sub> passed at 50° for 4 hrs.	0.45	0.4	0.0	0.504	1.42	0.0	0.512	1.50	0.05	0.537	1.9	0.25	0.589	2.0	0.262
2. H <sub>2</sub> passed under pressure at 30°	"	"	"	0.738	1.52	0.05	0.776	1.73	0.22	0.79	2.1	0.64	0.87	2.5	0.92
3. H <sub>2</sub> passed under pressure at 50°	"	"	"	0.526	1.30	0.0	0.623	1.45	0.06	0.76	2.0	0.35	0.832	2.5	0.48
4. H <sub>2</sub> passed under pressure at 70°	"	"	"	0.652	1.55	0.10	0.697	1.73	0.20	0.794	2.0	0.52	0.872	2.52	0.90
5. Control	"	"	"	0.874	2.1	0.20	1.24	2.58	0.48	1.84	2.9	0.98	2.52	3.6	2.45

above set of experiments, storage of the fat in atmospheres of CO<sub>2</sub> and N<sub>2</sub> at the room temperature was carried out, the respective gases being also passed for a period of 2 hours (Table IV). The results show that inert atmosphere has in general a retarding effect, but still hydrogen gives better result.

TABLE IV

*Effect of storage of butter-fat under different gas packages.*

Description.	Initial.			After 30 days.			After 60 days.			After 90 days.			After 120 days.		
	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.
1. CO <sub>2</sub>	0.45	0.4	0.0	0.75	2.1	0.15	0.78	2.58	0.32	0.86	2.9	0.54	0.98	3.6	0.64
2. Nitrogen	"	"	"	0.65	2.0	0.10	0.72	2.58	0.20	0.89	2.9	0.32	0.97	3.6	0.53
3. Hydrogen	"	"	"	0.74	1.64	0.0	0.78	1.88	0.15	0.88	2.2	0.42	0.91	2.8	0.45
4. Control	"	"	"	0.87	2.1	0.20	1.24	2.58	0.48	1.84	2.9	0.98	2.52	3.6	2.45

TABLE V  
*Effect of different antioxidants on butter-fat at room temperature.*

Antioxidants.	Initial.			After 30 days.			After 60 days.			After 90 days.			After 120 days.		
	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.	A.V.	K.N.	P.V.
1. Catechol	0.45	0.4	0.0	0.784	1.18	0.10	0.838	1.50	0.188	0.894	2.1	0.210	1.0	2.65	0.239
2. Pyrocatechol	"	"	"	0.753	1.17	0.05	0.835	1.49	0.20	0.893	2.06	0.247	1.07	2.51	0.881
3. Hydroquinone	"	"	"	0.753	1.17	0.05	0.831	1.49	0.157	0.927	2.0	0.197	1.022	2.50	0.336
4. Pyrogallol	"	"	"	0.578	0.85	0.02	0.677	0.94	0.055	0.774	1.01	0.10	0.852	1.04	0.121
5. Gallic acid	"	"	"	0.659	1.2	0.08	0.694	1.54	0.18	0.782	2.14	0.30	0.873	2.7	0.420
6. Pyrocatechnic acid	"	"	"	0.721	1.15	0.05	0.805	1.46	0.157	0.894	1.80	0.196	0.999	2.18	0.834
7. Oxalic acid	"	"	"	0.690	1.01	0.15	0.892	1.23	0.924	1.027	1.5	0.593	1.204	1.9	0.784
8. Maleic acid	"	"	"	0.784	1.17	0.17	0.841	1.6	0.40	0.927	2.10	0.542	1.044	2.44	0.672
9. Malonic acid	"	"	"	0.502	1.16	0.15	0.777	1.54	0.30	0.927	2.18	0.45	1.055	2.62	0.704
10. Coumarin	"	"	"	0.753	1.26	0.15	0.974	1.8	0.39	1.58	2.68	0.82	2.40	3.4	1.602
11. Tartaric acid	"	"	"	0.724	1.22	0.12	0.776	1.6	0.847	0.993	2.15	0.513	1.18	2.68	0.648
12. Citric acid	"	"	"	0.753	1.20	0.10	0.847	1.52	0.25	0.868	2.10	0.38	0.984	2.6	0.508
13. Sod. Pot. tartrate	"	"	"	0.690	1.22	0.12	0.714	1.7	0.31	0.732	2.2	0.419	0.804	2.65	0.502
14. Sod. citrate	"	"	"	0.690	1.08	0.05	0.743	1.44	0.15	0.795	1.94	0.306	0.875	2.20	0.370
15. Control	"	"	"	0.874	2.1	0.20	1.24	2.58	0.48	1.84	2.9	0.98	2.52	3.6	2.45

Considering the most important groups of antioxidants that are generally used in the preservation of foods we find that compounds rich in hydroxyl groups,

especially the phenolic and enolic in character, are predominant. We therefore studied the effect of a few substances of the quinol group, the pyrogallol group and also some of the acidic antioxidants and their salts (Table V). It may be seen that the polyhydroxy compound, pyrogallol exerts maximum effect of retardation. Then comes catechol and hydroquinone. Among the acids and their salts, the effect of sodium citrate and sodium potassium tartrate is maximum.

The experiments on the antioxidant studies were carried out by fortifying the fat with vitamins A and C (Table VI). It is seen that combination of the vitamins produces the desirable result.

TABLE VI

*Butter fat kept in presence of vitamin A & C.*

Description.	Initial.	After 30 days.			After 60 days.			After 90 days.			After 120 days.		
	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.	A.V.K.N.P.V.
1. Ascorbic acid (0.1%)	0.45 0.4 0.0	0.721 1.4 0.0	0.754 1.64 0.05	0.828 1.9 0.20	0.922 2.2 0.36								
2. $\alpha$ -Tocopherol acetate (0.005%)	.. ..	0.715 1.45 0.0	0.748 1.68 0.02	0.794 2.0 0.05	0.888 2.8 0.075								
3. Ascorbic acid (0.1%)+ $\alpha$ -tocopherol acetate (0.002%)	.. ..	0.702 1.20 0.0	0.715 1.24 0.0	0.718 1.3 0.05	0.788 1.45 0.064								
4. Control	.. ..	0.874 2.1 0.2	1.24 2.58 0.48	1.84 2.9 0.98	2.52 3.6 2.45								

Most experiments on antioxidant studies are carried out at temperatures ranging from 70° to 110°, and in presence of other accelerating factors; but very few of the experimental conditions resemble those actually encountered in practice, since it is quite apparent that the antioxidants may be affected appreciably by changes in the condition of testing, and there has been some confusion in interpreting the results carried out at higher temperatures. Of course, there is no denying in the fact that the antioxidants, which protect fats at higher temperatures, will also be able to protect them at ordinary temperatures. But there also exist some exceptions. The experiments in this paper were carried out at room temperature and time required to reach a peroxide value of 2 ml. per g. was regarded as end of the induction period. The protection factor with the best of the antioxidants are given approximately in Table VII. The concentration of the antioxidants used in these experiments was 0.02%.

TABLE VII

*Protection factors of some antioxidants with respect to butter-fat.*

Antioxidants.	Conc.	Protection factor.	Antioxidants.	Conc.	Protection factor.
Pyrogallol	0.02%	6.2	Hydroquinol	0.02%	5.5
Hydrogen (60°)	—	6.0	Sodium citrate	0.10	4.85
Catechol	0.02	5.8	Oxalic acid	0.10	2.7
Gallic acid	0.02	5.6	Coumarin	0.10	0.4
Pyrocatechol	0.02	5.5			

## DISCUSSION

The effect of dissolved hydrogen on retardation of rancidity of butter-fat is very remarkable as it appears from Tables I, II and III. Whilst hydrogen practically stops the hydrolytic rancidity of butter-fat for a period of five months

FIG. 1.

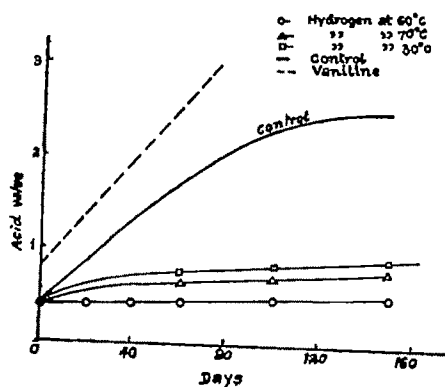
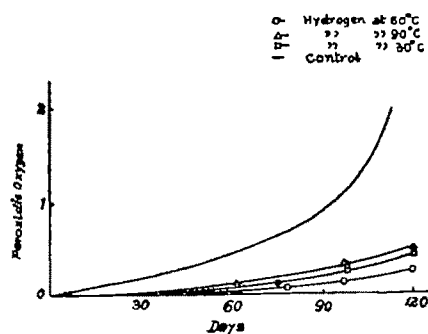


FIG. 2.



(Fig. 1), it simultaneously retards the oxidative rancidity to a very great extent. Organoleptic rancidity, however, becomes evident at the end of this period. The behaviour of hydrogen with butter-fat as regards protection is most marked with its increase in solubility with rise of temperature up to 50° to 60° above which the diminished action is probably due to the accelerating effect of temperature on

rancidity (Fig. 2). Storage with hydrogen under pressure at the different temperature does not, however, offer any additional protection to the fat (Fig. 3).

The experiments on gas packing with  $H_2$ ,  $N_2$  and  $CO_2$  with simultaneous

FIG. 3.

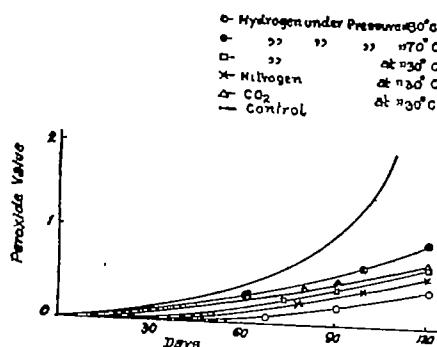
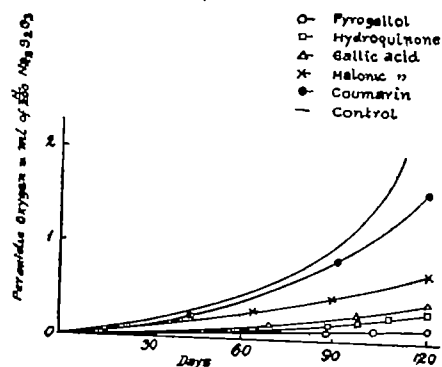
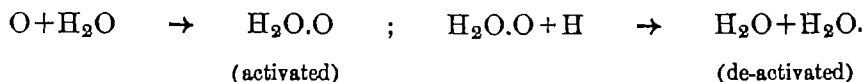


FIG. 4.



passage of the gas for 2 hours show a marked improvement on keeping quality as regards peroxide (Fig. 3) and acid values. We know that oxygen is necessary in order to produce the oxidative rancidity and that rancidity is primarily due to the presence of dissolved oxygen in the fat and it is this dissolved oxygen that activates the water molecules as also affects the unsaturated acids resulting in hydrolytic and peroxidic rancidity. In the light of the above experimental results (Tables II & III) it is well to presume that the dissolved hydrogen immobilises the activity of oxygen molecules probably thus :



An examination of Table V reveals that polyphenolic antioxidants, especially pyrogallol and gallic acid, are the most efficient retarder of rancidity of butter-fat. The behaviour of pyrogallol may be assumed to be due to its very enhanced affinity for oxygen. The salts of the organic acids are more marked in behaviour than the parent acids (Fig. 5). This is, however, contrary to the observation of Greenbank and Holm (*Ind. Eng. Chem.*, 1934, 25, 242). Coumarin is almost inactive (Fig. 4). Hydrogen (60°) (Table VII) secures a very high place in the list of antioxidants and large scale experiments on preservation of fats with this reagent is worth attempting.



Of the vitamins tested,  $\alpha$ -tocopherol acetate (quinol group) and 1-ascorbic acid, we find that the former is a very good antioxidant in as much it is a fat-soluble vitamin. Ascorbic acid is much less active (Fig. 6), though a very good synergistic effect is observed when used in combination with  $\alpha$ -tocopherol. A difficulty in the

FIG. 5

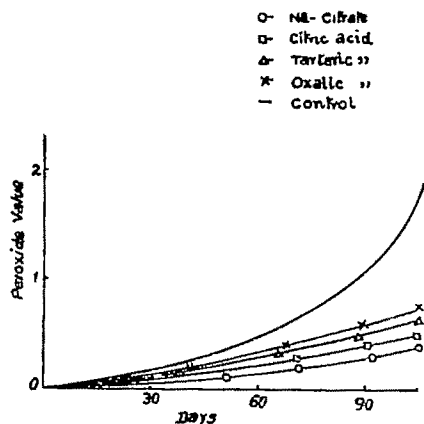
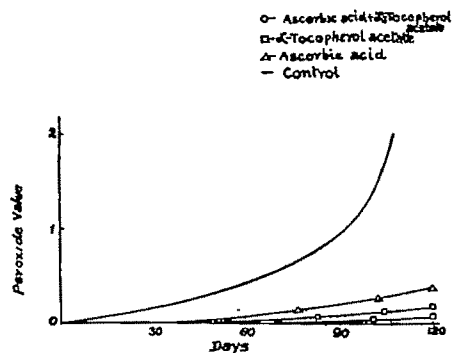


FIG. 6



use of ascorbic acid as an antioxidant is that it is insoluble in fats. The fact that the ester of 1-ascorbic acid with fatty acids like palmitic and stearic are quite fat-soluble, makes its incorporation much easier in such forms. The behaviour of these fatty acid esters of ascorbic acid with butter-fat will be published in a later communication.

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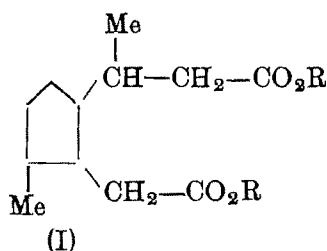
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SYNTHESIS OF THE DIETHYL ESTER OF THE DICARBOXYLIC  
ACID,  $C_{12}H_{20}O_4$  - A DEGRADATION PRODUCT OF THE  
SESQUITERPENE, GUAIOL

BY PASUPATI SEN-GUPTA, KAMALA KINKAR CHAKRABORTI AND  
BIDYUT KAMAL BHATTACHARYYA

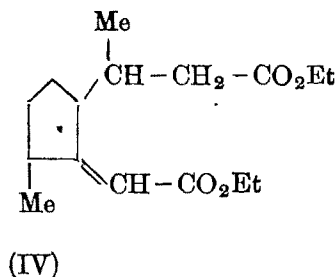
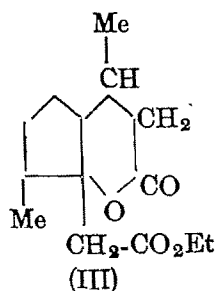
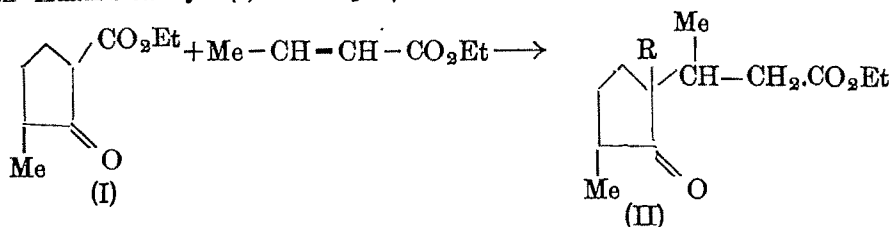
Michael condensation between ethyl 3-methylcyclopentanone-1-carboxylate and ethyl crotonate, followed by hydrolysis and esterification, furnishes (II, R=H) which on Reformatsky's reaction, followed by unsaturation and hydrogenation yields (I, R=Et).

Plattner *et al.* (*Helv. Chim. Acta*, 1940, 23, 897 ; 1941, 24, 191 ; 1942, 25, 581) obtained the dicarboxylic acid (I, R=H) by the degradation of the sesquiterpene alcohol, guaiol.



The diethyl ester of the acid (I) has been synthesised according to the method of Bhattacharyya (*J. Indian Chem. Soc.*, 1945, 22, 214) along the following line.

Ethyl 3-methylcyclopentan-2-one-1-carboxylate is condensed with ethyl crotonate in presence of piperidine in poor yield. But the same condensation with the aid of potassium ethoxide furnishes a good yield of the condensation product (II, R=CO<sub>2</sub>Et). Moreover, no appreciable disruptive effect of potassium ethoxide on the substituted  $\beta$ -keto ester formed is observed (*cf.* Bhattacharyya, *loc. cit.*). The compound (II, R=CO<sub>2</sub>Et) is hydrolysed and esterified. The action of zinc and ethyl bromoacetate on (II, R=H) yields the lactone (III) which on successive treatment with phosphorus pentachloride, alcohol, alcoholic potash and then with sulphuric acid and alcohol gives (IV). On catalytic hydrogenation with Adam's catalyst (I, R=CO<sub>2</sub>Et) is obtained.



## E X P E R I M E N T A L.

*Ethyl 3-Methylcyclopentan-2-one-1-(β-n-butyrate)-1-carboxylate* (II, R = CO<sub>2</sub>Et).—Ethyl 3-methylcyclopentan-2-one-1-carboxylate (17 c.c., Cornubert and Borrel, *Bull. soc. chim.*, 1930, 47, 301) was mixed with ethyl crotonate (17 c.c.) and piperidine (5 c.c.) when the mixture became slightly warm. It was heated on the water-bath for 24 hours. The cooled product was diluted with ether and the ether extract was washed with dilute hydrochloric acid and dried. Ether was driven off and the residue distilled, b. p. 164-66°/7.5 mm., yield 4 g.

The following experiments were carried out according to Bhattacharyya (*loc. cit.*).

The above condensation was performed with the β-keto ester (24 g.) and ethyl crotonate (20 g.) in presence of potassium ethoxide to yield 27 g. of the desired ester. (Found : C, 63.84 ; H, 8.6. C<sub>15</sub>H<sub>24</sub>O<sub>5</sub> requires C, 63.38 ; H, 8.44 per cent).

*3-Methylcyclopentan-2-one-1-β-n-butyric Acid* (II, R = H).—The above compound (23 g.) was hydrolysed and distilled, b. p. 140-150°/2 mm., yield 12 g. (Found : C, 64.83 ; H, 8.21. C<sub>10</sub>H<sub>16</sub>O<sub>3</sub> requires C, 65.21 ; H, 8.69 per cent).

*Ethyl 3-Methylcyclopentan-2-one-1-β-n-butyrate*.—The above acid (12 g.) was esterified with alcohol and sulphuric acid ; b. p. 125-30°/10 mm., yield 11 g. (Found : C, 67.53 ; H, 9.02. C<sub>12</sub>H<sub>20</sub>O<sub>3</sub> requires C, 67.92 ; H, 9.43 per cent).

The semicarbazone was prepared as usual and crystallised from ethanol, m. p. 156°. (Found : C, 57.77 ; H, 8.5. C<sub>13</sub>H<sub>23</sub>O<sub>3</sub>N<sub>3</sub> requires C, 57.99 ; H, 8.55 per cent).

*δ-Lactone of 2-Hydroxy-2-(carbethoxymethyl)-3-methylcyclopentane-1-β-n-butyric Acid* (III).—The Reformatsky's reaction was carried out with the keto-ester (11 g.), ethyl bromoacetate and zinc as usual, b. p. 146-50°/3 mm., yield 7 g. (Found : C, 66.7 ; H, 8.4. C<sub>14</sub>H<sub>22</sub>O<sub>4</sub> requires C, 66.15 ; H, 8.6 per cent).

*Ethyl 2-Methyl-5-(β-n-butyrate)-cyclopentilidene-acetate*. (IV).—Phosphorus pentachloride (5 g.) was slowly added to the above δ-lactonic ester (III, 7 g.). It was then allowed to stand overnight. The clear solution, thus obtained, was poured into alcohol and allowed to stand for 1 hour and then refluxed for 1½ hours. The product was worked up in the usual way. A molecule of hydrochloric acid was split up with methanolic potash and the crude product was esterified with alcohol and sulphuric acid and worked up, b. p. 155°/9 mm., yield 0.8 g. (Found : C, 68.47 ; H, 9.2. C<sub>16</sub>H<sub>26</sub>O<sub>4</sub> requires C, 68.09 ; H, 9.22 per cent).

*Ethyl 3-Methylcyclopentane-2-carbethoxymethyl-1-β-n-butyrate* (I).—The above unsaturated ester was hydrogenated and distilled, b. p. 156°/11 mm. (Found : C, 67.3 ; H, 9.65. C<sub>16</sub>H<sub>26</sub>O<sub>4</sub> requires C, 67.6 ; H, 9.86 per cent).

The ester on hydrolysis furnished a gummy acid which failed to crystallise.

Our best thanks are due to Prof. D. K. Banerjee for his valuable advice and encouragement during the course of this investigation and to the Trustees of Sir P. C. Ray Research Fellowship Fund for the award of a fellowship to one of us (B. K. B.).

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## COAGULATION OF COLLOIDS BY BIMETALLIC JUNCTIONS

By P. P. GYANI

The effect of bimetallic couples such as Mg-Fe, Mg-Zn, Mg-Mn, Mg-Cu and Mg-Ag has been studied with respect to coagulation of colloidal solutions of  $\text{Fe}_2\text{O}_3$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{As}_2\text{S}_3$  and  $\text{V}_2\text{O}_5$ . The rate of coagulation has been found to vary with the nature of the couple and the charge of the colloids and the function of evolved hydrogen bubble in the coagulation phenomenon discussed.

In a previous note from this laboratory (Ganguly, *Curr. Sci.*, 1941, 10, 75) it has been shown that bimetallic junctions (*e.g.* iron-aluminium couple) can coagulate colloidal solutions. It has also been pointed out that coagulation always proceeds from certain active points on the couple and it occurs most at the points where the active hydrogen is most vigorously evolved. In the present paper the effect of bimetallic couples has been studied in detail. An attempt has also been made to see whether atomic hydrogen plays any part during the coagulation process.

### EXPERIMENTAL

Four colloidal solutions, two positively charged and two negatively charged, were selected for investigation. These were prepared as follows.

*Ferric Oxide Sol.*—A few drops of 30% solution of ferric chloride were added to 500 c.c. of briskly boiling distilled water. A deep brown, transparent, positively charged sol was obtained.

*Aluminium oxide sol* was prepared according to the method of Crum (*Annalen*, 1853, 89, 156) by prolonged heating of a little aluminium acetate with a large volume of water on the water-bath till no smell of acetic acid was perceptible. A slightly opalescent, positively charged sol was obtained. It was practically free from acid.

*Arsenious sulphide sol* was prepared by the method of Linder and Picton (*J. Chem. Soc.*, 1892, 61, 137) as follows: arsenious oxide (0.5 g.) was boiled with 500 c.c. distilled water till solution was complete. When cooled, a current of  $\text{H}_2\text{S}$  was passed through the solution till no more deepening of colour took place. Excess of  $\text{H}_2\text{S}$  was removed by passing a rapid stream of hydrogen gas through the solution. The solution was filtered and kept in a stoppered flask.

*Vanadium pentoxide sol* was prepared by the method of Biltz. Ammonium vanadate (7g. approx.) was triturated in a mortar with hydrochloric acid. The red precipitate was filtered and washed continuously till the filtrate assumed a dark red colour. The bulk of the precipitate was then transferred to a flask and shaken up with 2 litres of distilled water. A clear, deep red, negatively charged sol was obtained.

*Bimetallic Couples.*—Five different couples were used, magnesium being one of the couple metals in each case. The other metals used for the bimetallic junctions were mono-, bi- and trivalent as follows :—Mg-Fe, Mg-Zn, Mg-Mn, Mg-Cu and Mg-Ag. They were prepared in the following manner, the experimental conditions being so fixed as to get reproducible activity for the couples as far as possible. Magnesium ribbon (10'' of 3 mm. width) was used in all cases. It was freshly cleaned with sand-paper, coiled up in the form of a spiral and then placed in the appropriate solution for 'coupling'. The solution taken for coupling was 25 c.c. in all cases. The strength of the solution as well as the time of coupling and washing are specified in Table I.

TABLE I

Couple.	Conc. of soln. for coupling.	Duration of coupling.	1st Wash- ing (under- tap).	2nd Wash- ing (50 c.c. dist.) water.	3rd Wash- ing (50 c.c. dist. water).	4th, Wash- ing (50 c.c. dist. water)
Mg-Fe	5% Soln. of $\text{FeSO}_4$ , $(\text{NH}_4)_2\text{SO}_4$ , $6\text{H}_2\text{O}$ (prepared immediately before use)	1 min.	15 sec	15 sec.	30 sec.	30 sec.
Mg-Zn	5% Soln. of $\text{ZnSO}_4$ , $7\text{H}_2\text{O}$ .	Do	"	"	"	"
Mg-Mn	5% Soln. of $\text{MnCl}_2$ , $2\text{H}_2\text{O}$	Do	"	"	"	"
Mg-Cu	2.5% Soln. of $\text{CuSO}_4$ , $5\text{H}_2\text{O}$	10 sec.	20 sec.	"	"	"
Mg-Ag	0.5% Soln. of $\text{AgNO}_3$	15	15	"	"	"

The arrangement employed for the experiments consisted of a stout glass vessel of about 100 c.c. capacity, fitted with a rubber stopper and a glass tube through it. To the lower end of the glass tube was attached a small hook made of platinum wire to support the couple. The vessel was connected to a gas burette, and was illuminated by an electric lamp screened by a ground-glass plate. A wire was introduced between the screen and the vessel in the case of experiments with  $\text{As}_2\text{S}_3$  sol.

To carry out an experiment, 50 c.c. of the sol were pipetted into the vessel. The couple, which was prepared as described above, was hung from the hook and the vessel closed tightly with the stopper. Then the vessel was gently tapped so that the couple fell into the sol. Observations of the progress of coagulation were made every minute. The experiments were conducted in a dark room and the bulb was switched on for a moment when an observation was made. In the case of  $\text{As}_2\text{S}_3$  and  $\text{Fe}_2\text{O}_3$  sols the vessel was allowed to stand undisturbed during coagulation, but with  $\text{V}_2\text{O}_5$  and  $\text{Al}_2\text{O}_3$  sols it was shaken at intervals.

When the desired point of coagulation had been reached the volume of evolved gas was measured with the help of the gas burette. As the final point of coagulation the following were taken :—

*Ferric oxide sol*—when tiny specks of coagulum were just visible.

*Vanadium pentoxide sol*—when the sol was filled with streaks of coagulum, and had become very viscous and the couple within the bottle could not be easily seen.

*Aluminium oxide sol*—when the sol became so viscous that bubbles of evolved gas could not escape.

*Arsenious sulphide sol*—when the wire just disappeared from sight due to the increasing turbidity of the sol.

Employing any particular sol and a particular couple, three or four experiments were made and the mean value taken as the correct one. The results are shown in Table II.

To test the effect of junction potentials, suitable external potentials were applied to 50 c.c. of the various sols by means of platinum electrodes (about 2 sq. cm. each and fixed 0.5 cm. apart). The external potential was increased by steps of 0.5 volt till at a particular potential coagulation occurred in 6 hours or less. Thus the minimum coagulation voltage for each sol was determined. The results are given in Table III.

TABLE II

Couple.	$\text{H}_2$ evolved.*	Coagul. time.	$\text{H}_2$ evolved.*	Coagul. time.	$\text{H}_2$ evolved.*	Coagul. time.	$\text{H}_2$ evolved.*	Coagul. time.
	$\text{As}_2\text{S}_3$ sol.		$\text{V}_2\text{O}_5$ sol.		$\text{Fe}_2\text{O}_3$ sol.		$\text{Al}_2\text{O}_3$ sol.	
Mg-Fe	3.0 c.c.	42 min.	5.2 c.c.	46 min.	3.9 c.c.	20 min.	4.6	20 min.
Mg-Cu	2.1	24	4.9	52	2.1	13	3.5	18
Mg-Mn	2.4	45	6.1	18	6.1	10	3.4	11
Mg-Zn	3.9	20	5.6	69	1.5	9	2.7	15
Mg-Ag	1.2	57	2.8	74	6.4	54	5.0	10 hrs.

\* At 760 mm. and at 28°.

TABLE III

Sol.	Minimum coagulation voltage.	
$\text{Fe}_2\text{O}_3$	Between 2.5 and 3.0 volts	
$\text{Al}_2\text{O}_3$	2.0	2.5
$\text{As}_2\text{S}_3$	3.0	3.5
$\text{V}_2\text{O}_5$	2.0	2.5

Of the colloids investigated coagulation by bimetallic junctions has been observed in each case. The rate of coagulation has been found to vary with the nature of the couple and the charge on the sol.

## DISCUSSION

The two most obvious explanations which suggest themselves for coagulation of colloids by bimetallic junctions are (i) that the junction potential, however small, acts like an applied external potential and causes coagulation and (ii) that the electrolytes, formed by the action of the couple on water or on traces of acids that remain in the sol, cause coagulation in the usual way by lowering the charge on the colloid particles.

It has been pointed out by Biltz (*Z. Electrochem.*, 1908, 14, 567) that the junction potential is not the predominant cause of coagulation. From Table III it is apparent that the minimum coagulation voltage of each of the sols used is above 2.0 volts for a time interval of 6 hours. The junction potentials of the couples used in those experiments are not likely to exceed 1.0 volt in any case. Hence, it is clear that the effect of the junction potential is very insignificant, specially in view of the coagulation in most of the cases under investigation having occurred within an hour as against the interval of 6 hours employed to find the minimum coagulation voltage.

After complete coagulation of the sol, the clear supernatant liquid and the coagulum were separately tested for the respective metal ions (ions of the metals constituting the couple). Traces of the metal ions were invariably found present either in the clear supernatant liquid or in the coagulum or in both. Thus the electrolytes appear to play an important part in the coagulation phenomenon with couples, and so Schulze-Hardy law regarding the valency of coagulating ion is expected to hold in the case of the negatively charged sols. In the five couples taken for the present experiments, Mg is a common constituent. Any difference in the coagulation of the same sol with different couples might reasonably be attributed to the difference in the other metals. Of the other metals used, Ag is monovalent, Cu, Zn and Mn, divalent and Fe, trivalent. The couples containing Ag satisfy Schulze-Hardy law in as much as coagulation is most delayed with these couples. But the action of the bi- and trivalent metals appears to be anomalous from the above point of view. For example, Fe being trivalent, has in none of the two cases ( $\text{As}_2\text{S}_3$  and  $\text{V}_2\text{O}_5$  sols) been found to be the most effective coagulant. It is with the couples containing bivalent metals that coagulation has been found to occur most readily. The definite presence of metallic ions in the system, however, leads to the conclusion that electrolytic coagulation is one of the important factors during flocculation by couples.

During the experiments with the couples, nascent hydrogen is always evolved, and probably in the atomic state, and the atomic hydrogen is likely to be one of the factors involving coagulation. A significant point is that the hydrogen is evolved in the form of fine tiny bubbles. Thus copious new surface is generated and the adsorption effects on the newly generated surface might be factors in the process of coagulation. Stark (*J. Amer. Chem. Soc.*, 1930, 52, 2730) points out that

a pure  $\text{Fe}_2\text{O}_3$  sol coagulates when a stream of an inert gas like hydrogen is passed through it. His experiments prove conclusively that coagulation is not due to impurities or free electrons associated with the gas. He postulates three possible mechanisms for the phenomenon. The effect might be due to increased collision of colloid particles consequent on agitation by gas bubbles; neutralisation of charge on the colloid by the charge on the gas bubble; adsorption effects on the gas-liquid interfaces produced by the gas bubbles. Stark himself has put forward abundant experimental evidence to show that "mechanical agitation is not the chief factor in the coagulation phenomenon with gas bubbles". Freundlich and Basu (*Z. physikal. Chem.*, 1925, 115, 203) found that agitation accelerated the rate of coagulation of  $\text{As}_2\text{S}_3$ ,  $\text{Fe}_2\text{O}_3$  and  $\text{V}_2\text{O}_5$  sols by electrolytes. Retardation occurred with  $\text{CuO}$  and gold sols, which was attributed to peptisation. Freundlich and Kroch (*ibid.*, 1926, 124, 155) observed coagulation of  $\text{CuO}$  sol on vigorous stirring. Rate of coagulation was found to be proportional to the square of the rate of stirring. Freundlich and Loebmann (*ibid.*, 1928, 139, 368) observed similar results with goethite sol. Only a definite fraction of the colloidal particles could be coagulated by stirring. Freundlich and Reiklinghausen (*ibid.*, 1931, 157, 325) hold the view that stirring as such is not the cause of coagulation because a  $\text{CuO}$  sol does not coagulate if the stirring is such that the surface of the liquid is not disturbed or renewed. On the other hand, Heller (*Compt. rend.*, 1934, 199, 354) maintains that particles can coagulate in the interior of a sol when they come into contact at high speeds. Heller (*ibid.*, 1934, 198, 1776) also claims that all sols can be mechanically coagulated under appropriate conditions as to pH etc. Thus, the role of agitation as a means of coagulation is still doubtful. If stirring is really a cause in the coagulation phenomenon, its speed must be a very important factor. A fairly vigorous stirring is essential for any appreciable amount of coagulation to occur. In the present experiments 1.2 to 6.4 c. c. of the gas have been evolved in 10 to 74 minutes. The rate of evolution of the gas is thus not very vigorous and it may be taken that mechanical agitation does not play any appreciable role.

It has been pointed out by several authors (Lenard, *Ann. Physik*, 1892, 46, 584; Thomson, McLean and Galt, *Proc. Roy. Soc.*, 1895, 57, A. 335; Coehn and Mozer, *Ann. Physik*, 1914, iv, 43, 1048) that bubbles of inert gases suspended in water are negatively charged. McTaggart (*Phil. Mag.*, 1913, vi, 27, 297; 1914, 28, 367; 1922, 44, 386) measured the charge on gas bubbles while immersed in a liquid by observing the rate of cataphoresis of small bubbles in water and solutions of electrolytes and non-electrolytes. He has also shown "that the magnitude and even the sign of this charge might be changed by the addition of small quantities of electrolytes". It is thus possible that coagulation of a sol might occur by neutralisation of the charge on the particle by the charge on the gas bubbles. If the charge on the bubble is opposite to that on the colloid particle, it is to be expected that the larger the volume of hydrogen evolved, the more rapid should be the coagulation. In the present experiments the volumes of hydrogen evolved have been plotted against the time of coagulation (curve not shown). With negatively charged sols the



time of coagulation with different couples increases as the amount of evolved hydrogen decreases. A somewhat opposite effect is observed with the positively charged sols. The nature of the curves obtained in the present experiments in the cases of negatively charged  $As_2S_3$  and  $V_2O_5$  sols is thus explicable. But in the absence of sufficient data we cannot be sure if this is actually the case.

If, on the other hand, the charge on the gas bubbles is of the same sign as that on the colloid particles, we might very well suppose that instead of coagulation, a stabilisation of the sol will occur. This might be the reason for the effect observed with positively charged sols in the present experiments. Even if the above effects do operate, they are only partial in view of other factors at work tending to coagulate the sol; for example, the electrolyte, formed by the action of the couple on the dispersion medium, has definitely a coagulating effect. Thus, inspite of the stabilising influence of the gas, the sol might ultimately coagulate, but the time of coagulation is prolonged.

Freundlich and Loebmann (*loc. cit.*) ascribed mechanical coagulation of goethite sol (by a current of air) to an enlargement of the surface of contact. Deutsch (*Z. physikal. Chem.*, 1928, 136, 353) observed a colour change in certain indicators when their aqueous solutions were shaken with air. He is of opinion that the increased aggregation of particles in the surface layer is due to the greater surface activity of larger particles. Freundlich and Recklinghausen (*loc. cit.*) have shown that for mechanical coagulation of colloids it is necessary that the surface be constantly changed. Thus it is established that the sol-air interface is an important factor in the coagulation phenomenon. Orientation of particles in the surface layer may be a secondary effect as has been pointed out by Freundlich and Loebmann (*Koll.-Chem. Beih.*, 1929, 28, 391). McTaggart has shown "that bubbles of inert gases suspended in solutions of electrolytes absorb on their surfaces the ions present in solution. In like manner colloids are adsorbed from dilute sols". The phenomenon of coagulation of colloids by hydrogen bubbles might then be pictured as follows. The bubble while rising through the sol absorbs particles of colloid. When these bubbles finally reach the surface of the liquid and burst, the excess is delivered to a very thin layer of the liquid at the top. The excess goes on increasing as more and more bubbles burst till finally the concentration limit at which the sol is stable is exceeded and the sol coagulates. It is likely that the evolved hydrogen functions in a similar manner in the present experiments also.

In conclusion the author thanks Principal Dr. P. B. Ganguly for his valuable suggestions and guidance and the authorities of the Patna University for the grant of a research scholarship which enabled him to carry out the work.

## FLUOBERYLLATES

BY BHUPESH CHANDRA PURKAYASTHA

From conductometric measurements it has been shown that four fluoberyllate ions namely,  $[\text{BeF}_3]'$ ,  $[\text{BeF}_4]''$ ,  $[\text{BeF}_5]'''$  and  $[\text{BeF}_6]''''$  exist in solution.

A search in the old literature for the double fluorides of beryllium reveals the existence of the salts of the type,  $\text{MF}, \text{BeF}_2$ ;  $2\text{MF}, \text{BeF}_3$ , where M stands for K, Na or  $\text{NH}_4$ . That beryllium in case of the latter compound ( $2\text{MF}, \text{BeF}_3$ ) is the constituent of a complex fluoberyllate ion  $[\text{BeF}_4]'$  and that this complex ion shows close analogy with sulphate ion have been well established by Sarkar and Ray (*J. Indian Chem. Soc.*, 1929; 6, 987).

The isolation of  $\text{NH}_4\text{F}, \text{BeF}_2$ , the salt of type  $\text{MF}, \text{BeF}_2$ , from phase rule study is of very recent origin (Novosselova and Averkova, *J. Gen. Chem. U. S. S. R.*, 1939, 9, 1064). Beryllium shows certain characteristic analogy with aluminium in the periodic table. The formation of beryllates and the role of  $\text{BeCl}_2$ , similar to that of  $\text{AlCl}_3$  in organic reactions, will serve as typical examples (Bredereck *et al.* (*Ber.*, 1939, 72B, 1414; *Z. angew. Chem.*, 1939, 52, 445). In case of aluminium, three double fluorides viz.,  $\text{NH}_4\text{F}, \text{AlF}_3$ ;  $2\text{NH}_4\text{F}, \text{AlF}_3$ ;  $3\text{NH}_4\text{F}, \text{AlF}_3$  have been isolated from phase rule study (Novosselova, *J. Gen. Chem. U. S. S. R.*, 1940, 10, 1547). From the facts stated above, the question naturally arises that in addition to  $[\text{BeF}_3]'$  and  $[\text{BeF}_4]'$  other complex fluoberyllates, analogous in composition to those of complex aluminium fluorides may also exist. Studies of such higher complex fluoberyllates in solution by physico-chemical measurements form the subject matter of the present investigation.

## EXPERIMENTAL

*Ammonium fluoberyllate* was prepared by digesting beryllium hydroxide in requisite amount of ammonium bifluoride and crystallising the product. The crystals were collected, dissolved in warm water and recrystallised. The crystals were washed twice with ice-cold water and finally with alcohol and dried in air. A stock solution was prepared and its strength determined by estimating beryllium and ammonia. The complex was decomposed by concentrated  $\text{H}_2\text{SO}_4$  in a platinum basin and beryllium precipitated as hydroxide and ignited to  $\text{BeO}$ . Ammonia

was estimated by distillation with alkali and absorbing the distillate in a standard acid and titrating back the excess acid.

*Beryllium fluoride* was prepared by heating ammonium fluoberyllate in an atmosphere of carbon dioxide in a crucible furnace at 300°, and finally at 400° for about an hour. A stock solution of the substance was prepared.

Beryllium was estimated as BeO in the same way as was done in the case of the previous compound. For the estimation of F' a known volume of the solution was evaporated to dryness with excess  $\text{Na}_2\text{CO}_3$  and the temperature was slowly raised till the mix melted and it was kept at fused state at high temperature for some time. The melt was cooled and extracted with water and filtered. In the filtrate fluoride was estimated as lead chlorofluoride. The ratio of Be to F was found to be 1 : 1.970.

*Beryllium sulphate* ( $\text{BeSO}_4 \cdot 4\text{H}_2\text{O}$ ) was prepared by digesting Kahlbaum's beryllium carbonate in  $\text{H}_2\text{SO}_4$  and crystallising the product. The crystals were dissolved in warm water, the solution acidified with sulphuric acid and recrystallised. The crystals were washed three times with ice-cold water and finally with alcohol till free from acid. A stock solution was prepared and its concentration checked by estimation of Be as  $\text{BeSO}_4$ .

*Ammonium Fluoride*.—The stock solution was prepared with Merck's  $\text{NH}_4\text{F}$  of reagent quality. The strength of the solution was ascertained by estimating both ammonia and fluorine in the same way as was done in previous cases.

The conductivity apparatus was fitted with amplifying system so that experimental error in determining resistance did not exceed 0.1%. The measurements were made in an electrically regulated thermostat by which the temperature could be kept constant within  $\pm 0.05^\circ$ .

In these observations the reciprocals of the observed resistances were sufficient to draw the curve showing divergence from the additivity rule. So the cell constant was not determined. The thermometric titrations were conducted in the same way as were done in a previous communication (Purkayastha and Sen-Sarma, *J. Indian Chem. Soc.*, 1946, 23, 32). The conductivity cell except the platinum plates were coated with paraffin.

Conductometric and thermometric measurements have been made with  $\text{BeSO}_4$ ,  $\text{BeF}_2$ , and  $(\text{NH}_4)_2\text{BeF}_4$  with  $\text{NH}_4\text{F}$  in each case. The breaks in the curve indicate the composition of the solution at which complex formations take place.

TABLE I

*Conductance measurements with BeSO<sub>4</sub> and NH<sub>4</sub>F*

Temp. = 30.0°.

1		2	3		4	5	6		7	8
$M/20 - \text{Be SO}_4$ soln. in c. c.	Water added in c. c.	Conductance of (1) $\times 10^3 = C_1$	$M/20 - \text{NH}_4 \text{ F soln.}$ added. in c. c.	Water added in c. c.	Conductance of (3) $\times 10^3 = C_2$	$C_1 + C_2 = C_3$	$M/20 - \text{Be SO}_4$ soln. in c. c.	$M/20 - \text{NH}_4 \text{ F}$ soln. in c. c.	Conductance of (6) $\times 10^3 = C_4$	$C_3 - C_4$
50	50	12.84	50	50	13.49	26.33	50	50	20.25	6.08
45	55	11.96	55	45	14.75	26.71	45	55	19.77	6.94
40	60	10.96	60	40	15.88	26.84	40	60	19.52	7.32
35	65	9.896	65	35	17.19	27.086	35	65	18.96	8.126
33.35	66.65	9.596	66.65	33.35	17.53	27.126	33.35	66.65	18.75	8.376
30	70	8.812	70	30	18.25	27.062	30	70	19.05	8.012
27	73	8.197	73	27	18.96	27.157	27	73	19.40	7.757
25	75	7.733	75	25	19.81	27.543	25	75	19.63	7.913
23	77	7.227	77	23	20.00	27.227	23	77	20.00	7.227
21	79	6.774	79	21	20.41	27.184	21	79	20.44	6.744
20	80	6.536	80	20	20.73	27.266	20	80	20.61	6.656
18	82	6.094	82	18	21.15	27.244	18	82	21.25	5.994
15	85	5.339	85	15	21.85	27.089	15	85	21.92	5.169
14.3	85.7	5.104	85.7	14.3	22.15	27.254	14.3	85.7	22.11	5.144
12	88	4.448	88	12	22.64	27.088	12	88	22.63	4.458
10	90	3.850	90	10	23.08	26.880	10	90	23.03	3.850
5	95	2.271	95	5	24.53	26.801	5	95	24.67	2.131

Difference from the least divergence from the additivity rule in each case has been plotted against composition (Fig. 1, curve I).

TABLE II

*Thermometric titration of  $(\text{NH}_4)_2\text{BeF}_4$  with  $\text{NH}_4\text{F}$ .*

$M/2$   $(\text{NH}_4)_2\text{BeF}_4$  soln (48 c.c.) was taken in the flask and  $3M$ - $\text{NH}_4\text{F}$  soln. added from the burette by 2 c.c. at a time.

$\text{NH}_4\text{F}$ added.	Thermo. readings.	$3 \times 10 \times$ diff. from orig. readings.	$\text{NH}_4\text{F}$ added.	Thermo. readings	$3 \times 10 \times$ diff. from orig. readings.	$\text{NH}_4\text{F}$ added.	Thermo. readings	$3 \times 10 \times$ d. ff. from orig. readings.
0 c.c.	2.800	0.000	12 c. c.	2.178	3.660	22 c.c.	2.128	5.160
2	2.270	0.900	14	2.168	3.960	24	2.120	5.400
4	2.240	1.800	16	2.155	4.350	26	2.112	5.640
6	2.220	2.400	18	2.143	4.710	28	2.104	5.880
8	2.200	3.000	20	2.137	4.890	30	2.099	6.030
10	2.189	3.310				32	2.093	6.210

$3 \times 10 \times$  difference from the original thermometer readings in each case has been plotted against the c.c. of ammonium fluoride added (Fig. 2, Curve II).

TABLE III

*Thermometric titration of  $\text{BeF}_2$  with  $\text{NH}_4\text{F}$ .*

$M/2$ - $\text{BeF}_2$  soln. (48 c.c.) taken in the flask and  $4M$ - $\text{NH}_4\text{F}$  soln. added from the burette by 2 c.c. at a time.

$\text{NH}_4\text{F}$ added.	Thermo. readings.	$\frac{1}{2} \times 10 \times$ diff. from orig. reading.	$\text{NH}_4\text{F}$ added.	Thermo. reading.	$\frac{1}{2} \times 10 \times$ diff. from orig. reading.	$\text{NH}_4\text{F}$ added.	Thermo reading.	$\frac{1}{2} \times 10 \times$ diff. from orig. reading.
0 c.c.	2.835	0.000	12 c. c.	2.266	2.845	26 c. c.	2.022	4.065
2	2.727	0.540	14	2.210	3.125	28	2.000	4.175
4	2.620	1.075	16	2.165	3.350	30	1.980	4.275
6	2.520	1.575	18	2.130	3.525	32	1.962	4.365
8	2.430	2.025	20	2.100	3.675	34	1.946	4.445
10	2.342	2.465	22	2.070	3.825	36	1.929	4.530
			24	2.048	3.935			

$\frac{1}{2} \times 10 \times$  difference from the original thermometer readings in each case has been plotted against the c.c. of ammonium fluoride added (Fig. 2, Curve III).

TABLE IV

*Conductometric titration of  $(\text{NH}_4)_2\text{BeF}_4$  with  $\text{NH}_4\text{F}$ .*Temp.  $-30.0^\circ$ .

$M/20$ - $(\text{NH}_4)_2\text{BeF}_4$  solution (60 c.c.) was taken in the cell and  $3M$ - $\text{NH}_4\text{F}$  solution added from a micro-burette.

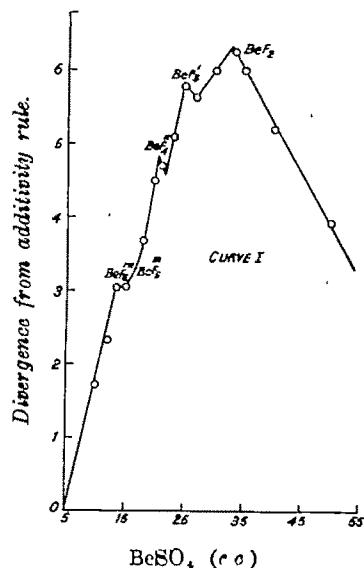
$\text{NH}_4\text{F}$ added.	Resistance.	$\frac{1}{2} \times$ diff. from final resistance.	$\text{NH}_4\text{F}$ added.	Resistance.	$\frac{1}{2} \times$ diff. from final resistance.
0.00 c.c.	22.57 ohms	6.530	1.75 c. c.	12.57 ohms	1.530
0.25	20.12	5.805	2.00	11.93	1.210
0.50	18.25	4.370	2.25	11.89	0.9400
0.75	16.66	3.575	2.50	10.92	0.7050
1.00	15.45	2.970	2.75	10.39	0.4400
1.25	14.33	2.410	3.00	9.919	0.2045
1.50	13.53	2.010	3.25	9.510	0.0000

$\frac{1}{2} \times$  difference from the final resistance has been plotted against mols. of ammonium fluoride added (Fig. 3, Curve IV).

## DISCUSSION

The curve I (Table I) showing divergence from the additivity rule in the conductometric measurements of  $\text{BeSO}_4$  with  $\text{NH}_4\text{F}$  has four clear maxima. The compositions of the solutions at these maxima indicate respectively

FIG 1



the formations of  $[\text{BeF}_2]$ ,  $[\text{BeF}_3]'$ ,  $[\text{BeF}_4]''$  and  $[\text{BeF}_6]'''$  in solution. There is a flattened portion of the curve lying in between the maxima due to the formation of  $[\text{BeF}_4]''$  and  $[\text{BeF}_5]'''$ . The flattened nature at this region of the curve is an indirect evidence for the formation of  $[\text{BeF}_5]'''$  in solution.

The curve III (Table III) due to the thermometric titrations of  $\text{BeF}_2$  with  $\text{NH}_4\text{F}$  has also four breaks which indicate the presence of  $[\text{BeF}_3]'$ ,  $[\text{BeF}_4]''$ ,  $[\text{BeF}_5]'''$  and  $[\text{BeF}_6]'''$  in solution as in the previous case.

The curves II and IV (Figs. 2 and 3) respectively due to thermometric and conductometric measurements of  $(\text{NH}_4)_2\text{BeF}_4$  with  $\text{NH}_4\text{F}$  show two clear breaks in each case. These breaks must be due to the formation of  $[\text{BeF}_5]'''$  and  $[\text{BeF}_6]'''$  in solution.

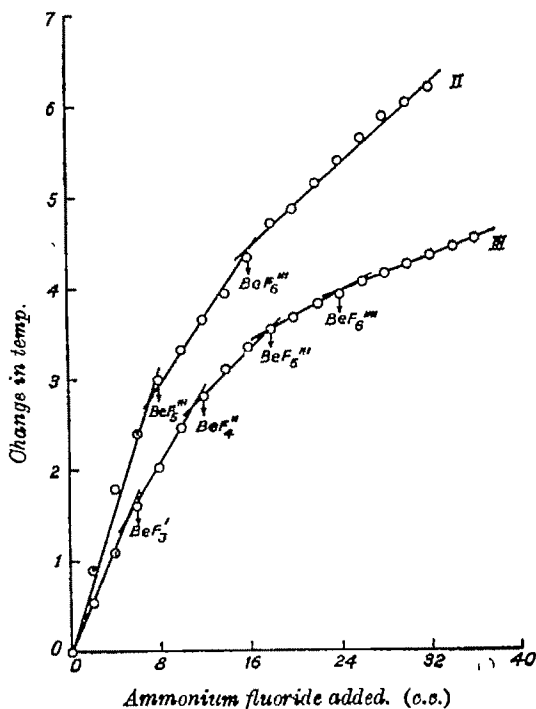
These conclusions have been drawn from two independent physical methods, which differ from each other in fundamental principle, one depending upon the colligative property of the solution and the other upon the temperature change serving as an index to chemical reactions.

Evidences derived from both the methods indicate that there exist four complex fluoberyllates, namely  $M[\text{BeF}_3]'$ ,  $M_2[\text{BeF}_4]''$ ,  $M_3[\text{BeF}_5]'''$  and  $M_4[\text{BeF}_6]'''$  where  $M$  stands for a monovalent cation.

From the evidences set forth above the previous idea that there is one single fluoberyllate  $[\text{BeF}_4]''$  or there are at least two ( $[\text{BeF}_3]'$  and  $[\text{BeF}_4]''$ ) is no longer tenable. Further, these evidences not only expand the idea as regards the number of fluoberyllates existing in solution and not only serve as instances for analogy of beryllium to aluminium but also establish the hexa co-ordination of beryllium in solution. Beryllium in consideration of its position in the periodic table with respect

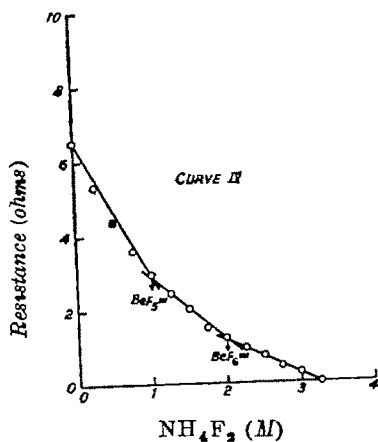
to boron, aluminium and magnesium is expected to exhibit co-ordination number higher than four.

FIG. 2.



Curve II—48 c.c. of  $M/2-(NH_4)_2BeF_4$  solution was taken in the flask and 3M- $NH_4F$  solution added from the burette.

FIG. 3.



Curve IV— $M/20-(NH_4)_2BeF_4$  soln. taken in the cell and 3M- $NH_4F$  added.

Curve III—48 c.c. of  $M/2 BeF_3$  soln. taken in the flask and 4M- $NH_4F$  soln. added.

A phase rule study with ammonium fluoberyllate and ammonium fluoride is in progress.

In conclusion the author expresses his deep gratitude to Dr. P. B. Sarkar for encouragements, helpful suggestions and laboratory facilities.

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## DIFFUSION AND AXIAL RATIO OF SHELLAC AND ITS CONSTITUENTS

BY SADHAN BASU

The values of the axial ratio, as obtained by the viscometric method for shellac, hard resin and soft resin, are found to compare favourably with those obtained by diffusion measurements.

Dimensions (effective length and breadth) of shellac particles and of the constituent resins have been calculated on the assumption that these are prolate spheroids.

In a previous communication (Basu, *J. Indian Chem. Soc.*, 1947, 24, 157) Kuhn's equation for the viscosity of solutions was applied to the case of shellac solution in determining the values of the axial ratios ( $a/b$ ) for hard resin, soft resin and dewaxed shellac. Measurement of free diffusion also affords an effective method for calculating the value of axial ratios, which, besides serving as an independent check of the results deduced from viscosity studies, is somewhat to be preferred as giving a clearer insight into the dissymmetry of the particles. Accordingly diffusion measurements have been carried out on shellac and its constituents and the results reported in the present communication.

Graham was the first to recognise the effect of particle size on the diffusion constant, and attributed the low values obtained for the diffusion constant in many cases to the smallness of the size of the pores of the membrane. This viewpoint has since changed and it is now assumed that diffusibility is determined by the intensity of kinetic activity and the frictional resistance experienced by the particles. The diffusion constant ( $D$ ) as deduced by Einstein theoretically (*Ann Physik*, 1905, 17, 549) is given by the equation,

$$D = \frac{RT}{N} \cdot \frac{1}{f} \quad \dots \quad (1)$$

where  $R$  is the gas constant,  $T$ , the absolute temperature,  $N$ , Avogadro number and  $f$ , the frictional coefficient. In a dilute solution, where there is little or no interaction between the dissolved particles, the frictional coefficient depends mainly on the size and shape of the particles; moreover, if the particles be spherical, then Stoke's law ( $f = 6\pi\eta r$ ) is applicable and equation (1) becomes

$$D = \frac{RT}{N} \cdot \frac{1}{6\pi\eta r} \quad \dots \quad (2)$$

where  $\eta$  is the viscosity of the solvent and  $r$ , the radius of the particle.

The calculation of molecular weight from the radius value obtained from equation (2) gave varying values for a protein molecule, which was construed to



indicate (Neurath, *J. Amer. Chem. Soc.*, 1939, **61**, 1841 ; Polson, *Kolloid Z.*, 1939, **87**, 149 ; Swedberg, *Proc. Roy. Soc.*, 1939, **B**, 127, 1) a high degree of dissymmetry in the dissolved molecules. For a particle of given volume the effect of shape may be expressed in terms of the diffusion constant as follows : Assuming that the particles are spherical,  $r$  can be calculated from the knowledge of the specific volume ; this, when substituted in (2), would give a theoretical value of  $D$ , termed  $D_0$ , which would be the value of the diffusion constant for spherical particles of the same size. A comparison of the observed value of  $D$  with this hypothetical value  $D_0$  would be a measure of the dissymmetry of the particles. Thus, for a spherical particle  $D/D_0$  will be 1 ; actually, however, for most macromolecular particles this value ranges from 1 to 100 depending on the degree of dissymmetry.

Several equations have been proposed from time to time to correct the diffusional data for molecular dissymmetry. Swedberg (*loc. cit.*) developed the equation

$$f/f_0 = \frac{RT/D}{6\pi\eta N \left( \frac{3MV}{4\pi N} \right)^{1/3}} \quad \dots \quad (3)$$

where  $f$  = the experimental molar frictional constant,  $f_0$  = the frictional constant for sphere of same mass,  $V$  = partial specific volume, other symbols having the same significance as before. The factor  $f/f_0$  is known as Swedberg's shape factor.

Attempts have been made by Perrin (*J. Phys. Radium*, 1936, **7**, 1) and Herzog (*Z. physikal. Chem*, 1934, **A**, 167, 329) to deduce a mathematical relation between the axial ratio and the shape factor, and the following equation has been obtained for a prolate spheroid

$$f/f_0 = \frac{\sqrt{1-b^2/a^2}}{(b/a)^3 \ln \left( \frac{1 + \sqrt{1-b^2/a^2}}{b/a} \right)} \quad \dots \quad (4)$$

where  $a$  = half-axis major and  $b$  = half-axis minor. Since, however, the frictional constant is inversely proportional to the diffusion constant, *i.e.*,

$$f/f_0 = D_0/D \quad \dots \quad (5)$$

equation (4) may be written as

$$D_0/D = \frac{\sqrt{1-b^2/a^2}}{(b/a)^3 \ln \left( \frac{1 + \sqrt{1-b^2/a^2}}{b/a} \right)} \quad \dots \quad (6)$$

Knowing  $D_0/D$  it should be theoretically possible to solve equation (6) for  $b/a$ . But instead of attempting a direct solution, the values of  $b/a$ , as obtained from viscometric measurements (Basu, *loc. cit.*), may be substituted in equation (6) and the resulting value of  $D_0/D$  compared with the observed value.

## E X P E R I M E N T A L

*Apparatus and Method*—The diffusion constants were measured by means of a diffusion cell first proposed by Northrop and Anson (*J. Gen. Physiol.*, 1929, 12, 543) and afterwards improved by McBain and co-workers (*J. Amer. Chem. Soc.*, 1931, 53, 59). Their method consists in separating two homogeneous solutions by means of an indifferent membrane, made of sintered glass plate, the diffusion gradient being confined within this membrane. The cell is shown diagrammatically in Fig. 1.

The cell was cleansed by sucking in chromic acid through the porous disc and then expelling the acid by applying pressure, after which it was thoroughly washed with distilled water and dried. The filling up of the cell was also effected by sucking in the required solution through the porous disc till it reached the level above the stop-cock which was then closed. The cell was then placed in a beaker containing pure solvent and left for an hour in order that a uniform diffusion gradient might set up within the diaphragm. It was then removed and after the adhering solvent had been wiped off, placed in another beaker containing the same volume of solvent as the solution inside, just touching the surface of the solvent in the beaker. The whole system was placed under a bell jar in order to prevent undue evaporation of the solvent. Evaporation in the bell jar itself was reduced to a minimum by saturating the space inside with the vapour of the solvent, before placing the system under it. Actually the solvent in the beaker was found to undergo practically no change in volume after 24 hours, the period of diffusion in each experiment.

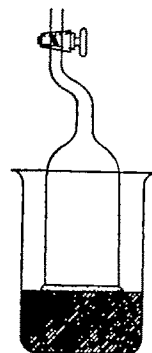


FIG. 1.

After 24 hours, the cell was taken out, wiped with filter paper (the inside of the tube above the stop-cock being also wiped), and the solution was extruded through the membrane. The concentration of the solution in the cell, as also in the beaker, was determined by means of a Dubosq colorimeter. The actual calculation of the diffusion constant from the experimental data was carried out by means of McBain's equation (applicable to the present system)

$$KD = \frac{\log_{10} c_0 - \log_{10} (c_0 - 2c)}{t} \quad \dots \quad (7)$$

where  $c_0$  = initial concentration in the cell,  $c$  = concentration in the beaker after diffusion,  $t$  = the time of diffusion in seconds and  $K$  = the cell constant. The cell constant was evaluated by measuring the diffusion constant of 0.1N-KCl, known to be 1.448 at 20° (International Critical Tables).

The methods used for separating hard and soft resins and also for preparing their alcoholic solutions were the same as described in a previous paper (Basu, *loc cit.*).

## RESULTS AND DISCUSSION

The value of the cell constant, as obtained by measuring the diffusion constant of 0.1N-KCl, was found to 0.1267. The experimentally found diffusion constants for dewaxed shellac, hard resin and soft resin are given in Table I.

TABLE I

	<i>t.</i>	<i>c.</i>	<i>c.</i>	$D \times 10^7$ .
Dewaxed shellac ...	24 hrs	5.010%	0.130%	20.53
Hard resin ...	24	4.989	0.110	16.90
Soft resin ..	24	3.110	0.105	28.08

Taking the molecular weights of dewaxed shellac, hard resin and soft resin respectively, as 1000, 1900 and 550, as obtained by cryoscopic method, the values of  $D_0/D$ , as obtained from Swedberg's and Herzog's equations (3 and 6), are given in Table II.

TABLE II

	<i>V.</i>	<i>a/b.</i>	<i>T.</i>	$\eta \cdot 10^5$ (in poise)	$(D_0/D)_S$	$(D_0/D)_H$
Dewaxed shellac ...	0.930	10.8	30°	10.1	1.49	1.55
Hard resin ...	0.934	11.7	30	10.1	1.56	1.60
Soft resin ...	0.925	7.8	30	10.1	1.37	1.42

$(D_0/D)_S$  and  $(D_0/D)_H$  represent the values obtained respectively from Swedberg's and Herzog's equations.

Concordant results have been obtained in all these cases, variation between the two sets of values never exceeding 4%. Still closer agreement may not be expected considering that the exact molecular weights of the substances are not known and no method is at present available for preparing absolutely pure samples.

There may, however, be certain objections to the calculation of the axial ratio from Herzog's equation. Firstly, it assumes the particles to be rigid, whereas in actual practice they may be 'soft' or flexible. Secondly, since no method is at present available to find out the extent of solvation and hence its effect on  $D_0$ , the  $D_0/D$  value, obtained by calculating  $D_0$  from the volume of the particles, will be inaccurate and so also the value of axial ratio deduced from it. Thus Polson (*Nature*, 1936, 137, 740) obtained by using this equation, the values for haemoglobin and insulin as 3.8 and 3.2 respectively as against 1.5 and 0.7 obtained by the X-ray method. In the present case, however, in the range of concentration studied, which was below 5% (Basu, *J Indian Chem. Soc.*, 1947, 24, 159), the particles are neither solvated, nor flexible, and therefore the concordant values of  $a/b$  obtained independently by the viscometric method and the diffusion method may be accepted as more or less the true values of  $a/b$  for shellac resins in solution.

Since the equation developed for a prolate spheroid is applicable in the case of shellac and its constituent resins, the assumption that particles in the dissolved state have got an effective volume equal to that of a prolate spheroid enables us to calculate the length and breadth of the molecules. The volume of the particle in the dissolved state is given by

$$\bar{V} = \frac{VM}{N} \quad \dots \quad \dots \quad (8)$$

where  $\bar{V}$  = partial specific volume,  $M$  = molecular weight and  $N$  = Avogadro number. Since the volume of a prolate spheroid is

$$\bar{V} = \frac{\pi SL^2}{6} \quad \dots \quad \dots \quad (9)$$

where  $S$  = major axis =  $2a$ , and  $L$  = minor axis =  $2b$ , we get

$$VM/N = \pi SL^2/6 \quad \dots \quad \dots \quad (9a)$$

$$\text{or } SL^2 = 6 MV/N\pi \quad \dots \quad \dots \quad (9b)$$

Thus from the value of  $SL^2$ , as obtained from (9b), and from the ratio  $S/L$  ( $= a/b$ ), we can calculate the values of  $S$  and  $L$  which are given in Table III.

TABLE III

		$S/L$	$S$	$L$
Soft resin	..	7.8	44.80 Å	5.74 Å
Hard resin	...	11.7	91.92	7.86
Dewaxed shellac	...	10.3	68.05	6.61

This type of calculation has been made in the case of polystyrene ("Second Report on Viscosity and Plasticity", 1938, p. 173) as also for cellulose acetate (Nils Gralen, Inaugural Dissertation, University of Uppsala, Sweden, 1944). For these substances, however, the particles are flexible and the results are therefore likely to be inaccurate. In the case of shellac, however, the results might be reasonably accurate since flexibility of the particles under the conditions of the experiment is negligible. But no final conclusion about these values can be drawn in absence of X-ray measurements.

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## SYNTHESIS OF SUBSTITUTED DINITROPHENYL KETONES AND PHENYLACETIC ACIDS. PART I.

BY A. B. SEN AND P. M. BHARGAVA

2 : 4-Dinitro-6-bromophenylacetone and 2 : 4-dinitro-6-bromophenylacetic acid have been prepared by the ketonic and acid hydrolysis respectively of the product obtained by the condensation of 1-chloro-2 : 4-dinitro-6-bromobenzene with ethyl acetoacetate. The ketone has been characterised by the preparation of suitable derivatives. The reduction of 2 : 4-dinitro-6-bromophenylacetic ester by tin and hydrochloric acid gave rise to an indole derivative.

The simple aromatic halogen compounds like chlorobenzene, do not react with the monosodium derivatives of acetoacetic or malonic ester, as the halogen atom in this case is very firmly fixed to the nucleus. The introduction of negative groups (like nitro), specially in the *ortho* and *para* positions to the halogen atom, however, makes it extremely labile and thus facilitates its replacement by various groups. Such compounds can also be condensed with acetoacetic or malonic ester. Considerable work has been done on this subject, the more important contributions being those of Richter (*Ber.*, 1888, 21, 2473), Heckmann (*Annalen*, 1884, 220, 137), Jackson (*Ber.*, 1889, 22, 1232), Reissert and Heller (*Ber.*, 1904, 37, 4634), Borsche (*Ber.*, 1909, 42, 601), Hantzsch and Pieton (*Ber.*, 1909, 42, 2126), Borsche and Rantscheff (*Annalen*, 1911, 379, 180), Borsche Bahr (*ibid.*, 1914, 402, 91), and Dey and Doraiswami (*J. Indian Chem. Soc.*, 1933, 10, 309).

The esters obtained as above by the condensation of the polynitro halogen compounds with acetoacetic or malonic ester also undergo ketonic and acid hydrolysis and thus provide a suitable method for the preparation of substituted phenylketones and phenylacetic acids.

In the present paper this reaction has been extended to 1-chloro-2 : 4-dinitro-6-bromobenzene with the object of obtaining the appropriate phenylacetone (which has been further characterised by the preparation of the phenylhydrazone and oxime) and phenylacetic acid. The reduction of 2 : 4-dinitro-6-bromophenylacetoacetic ester by tin and hydrochloric acid, which yields an indole derivative, has also been carried out during the course of the work.

### EXPERIMENTAL

2 : 4-Dinitro-6-bromophenylacetoacetic Ester.—The monosodium derivative of acetoacetic ester was prepared as usual from sodium tape (3.5 g., 0.15 mole) and ethyl acetoacetate (19.5 g., 0.15 mole), dissolved in 50 c.c. of dry ether, in a flask fitted with a reflux condenser and a mechanical

stirrer. 1-Chloro-2:4-dinitro-6-bromobenzene (21.1 g, 0.075 mole) (Sane and Joshi, *J. Indian Chem. Soc.*, 1933, 10, 459) was then added under ice-cooling and the mixture refluxed for 6 hours. Next day the reaction mixture was shaken twice with 100 c.c. of water and then once with 100 c.c. of 1% caustic soda solution. The combined extracts were acidified with dilute nitric acid, when a red oil separated. The aqueous portion was decanted off, the oil redissolved in 1% caustic soda solution and extracted with ether to remove any unreacted acetoacetic ester. It was then reprecipitated with dilute nitric acid, dissolved in cold alcohol and left over for slow evaporation. After a week's standing, dark red crystals separated, which were filtered and dried. Further evaporation of the filtrate yielded a semisolid mass. The crystalline product for purification was redissolved in alcohol, filtered and left for evaporation, when brown-red needles were obtained, m.p. 73-74°, yield 24.7 g. (88% of theory). (Found: N, 7.36.  $C_{12}H_{11}O_7N_2Br$  requires N, 7.47 per cent).

2:4-Dinitro-6-bromophenylacetone was obtained by dissolving the finely powdered ester (2.5 g.) in concentrated sulphuric acid (25 c.c.) to which 7 c.c. of water were then added under constant stirring. This resulted in the evolution of carbon dioxide and when this ceased to evolve, the clear brown solution was poured on crushed ice. The raw ketone, which separated as a semisolid mass, was left overnight in a frigidaire and then filtered. This was then dissolved in alcohol and left over for slow evaporation. The crystals which separated were further purified by dissolving in hot alcohol, filtering and leaving the filtrate to evaporate when fine brown needles of m.p. 111-12° were obtained in quantitative yield (2g.). (Found: N, 9.42.  $C_9H_7O_5N_2Br$  requires N, 9.24 per cent).

The *oxime* was prepared by dissolving the above ketone (1g.) in alcohol and adding to it hydroxylamine hydrochloride (0.5 g.) followed by caustic soda solution till it turned just alkaline to phenolphthalein. After refluxing the mixture for 1 hour, the contents were cooled and poured in 100 c.c. of water when a colloidal suspension was obtained. This was allowed to stand overnight in the frigidaire and then left to settle at room temperature for a week after which it was filtered and purified by washing it with boiling alcohol; the blackish brown product did not melt, yield 0.6 g. (60% of theory). (Found: N, 12.81.  $C_9H_8O_5N_3Br$  requires N, 13.20 per cent).

The *phenylhydrazone* was obtained by dissolving the ketone (0.5 g.) in minimum quantity of alcohol and adding to it about 8 drops of phenylhydrazine. The mixture was refluxed on a water-bath for 15 minutes, and cooled; the phenylhydrazone separating was then filtered, washed with a little alcohol and recrystallised from hot alcohol, m.p. 127°, yield 0.65 g. (quantitative). (Found: N, 14.30.  $C_{15}H_{13}O_4N_4Br$  requires N, 14.25 per cent).

2:4-Dinitro-6-bromophenylacetic Acid.—The ester (1 g.) was refluxed for half an hour with 20% alcoholic potash (4.5 c.c.) to which a few drops of water had been added. The solution was cooled and acidified with dilute hydrochloric acid.

The alcohol was distilled off and the solution allowed to cool and stand overnight. The product which separated out was filtered at the pump and washed several times with cold alcohol to remove the unchanged dinitrobromophenylacetoacetic ester, leaving the pure brown-black acid. It was recrystallised by dissolving in hot alcohol, filtering and allowing the filtrate to evaporate, m.p.  $184^{\circ}$ , yield 0.5 g. (quantitative). (Found : N, 8.76.  $C_8H_5O_6N_2Br$  requires N, 9.18 per cent).

*2-Methyl-3-ethylcarboxy-5-bromo 7-aminoindole*.—2:4-Dinitro-6-bromophenylacetoacetic ester (2.5 g.) was dissolved in alcohol (15 c.c.) on a water-bath and a mixture of 2.5 c.c. of stannous chloride solution and 6 c.c. of concentrated hydrochloric acid was added. The dark brown solution was warmed for a few minutes and then cooled under brisk stirring. Excess of granulated tin was then added and the solution refluxed for 3 hours on a water-bath. End of the reaction was tested by treating a drop of the reaction mixture with NaOH, when no strong colour was developed and the free indole derivative got precipitated in microscopic form. The refluxed solution was filtered hot from excess of tin, and the alcohol evaporated from the filtrate, when the tin double salt separated out. Hydrochloric acid was added to dissolve the precipitate as much as possible and the solution filtered. The tin was precipitated completely from the filtrate by hydrogen sulphide. The solution obtained containing the hydrochloride of the amine was neutralised with ammonia, when a white, heavy and flocculent precipitate was obtained, which turned black on exposure to air.

The product after repeated crystallisation from hot alcohol gave a dark coloured crystalline substance which did not melt. (Found : N, 9.92.  $C_{12}H_{13}O_2N_2Br$  requires N, 9.45 per cent).

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## STUDIES IN CELLULOSE ACETATE, PART II.

BY PIJUSH KANTI CHOUDHURY

During the preparation of cellulose acetates, an acetate having a theoretical acetic acid content of 62.5% corresponding to tri-acetate is produced at the early stage; but with the progress of reaction, this acetate passes through several intermediate stages yielding products soluble both in chloroform and in acetone and finally di-acetate is formed having acetic acid content of 48.8%. Hydrolysis of tri-acetate to di-acetate has been effected without the presence of acetic acid or water.

Cellulose tri-acetate contains 44.8% acetyl or 62.5% acetic acid content, the di-acetate, 35.0% acetyl or 48.8% acetic acid content and the mono-acetate, 21.1% acetyl or 29.4% acetic acid content.

That the tri-acetate with 62.5% acetic acid content is a definite chemical compound has been established (Hess, "Die Cellulose", 1928; Hess and Lijubitsch. *Ber.*, 1928, **61**, 1460; Barnett, *J. Soc. Chem. Ind.*, 1921, **40**, 8; Ost, *Z. angew. Chem.*, 1919, **32**, 66). Hess, Schultz and Messmer (*Annalen*, 1925, **444**, 266) have shown that cellulose tri-acetate, soluble in chloroform, can be prepared in crystal form and is the normal acetylation product of chemically unchanged cellulose. This view has been confirmed by X-ray analysts.

Tri-acetate is soluble in chloroform but the film, made out of it, is weak and brittle (*cf.* Ost, *loc. cit.*). Hence for technical purposes, tri-acetate is useless.

Miles (B. P. 19330, 1905) by the partial hydrolysis of the tri-acetate with 50% acetic acid obtained an acetone-soluble di-acetate. Dreyfus (F. P. 478 023, 1914; B. P. 312,098, 311,790, 308,322; U. S. P. 1,711 111) too, prepared the di-acetates from tri-acetates by hydrolysis using water alone. Di-acetates give much clearer and tougher films. Di-acetates prepared by Miles' process give acetic acid content varying between 51 and 58%. Di-acetates are generally soluble in acetone but insoluble in chloroform.

Ost (*loc. cit.*) has investigated the solubility of cellulose acetate in various solvents and found the acetic acid content of the cellulose acetate to be the guiding factor in its solubility in different solvents. The cause for the dissolution of the secondary or di-acetates in acetone and the property of dispersion of the resultant product in acetone have been ascribed to the amount of acetic acid and water present during the degradation of primary acetate to secondary acetate.

Yarsley ("Über die Herstellung und physikalischen Eigenschaften der Cellulose Acetate") corroborated the views of Ost and showed definitely that contrary



to the observations of Miles, Dreyfus and others, primary or tri-acetates, prepared by him, were soluble both in acetone and in chloroform. But the most satisfactory secondary or di-acetates were obtained from those tri-acetates which were difficultly soluble in acetone. Di-acetates prepared by him gave 53% acetic acid content.

According to Marsh and Wood ("An Introduction to the Chemistry of Cellulose", 1945, p. 327) solubility in chloroform is almost entirely determined by the extent of acetylation and increases rapidly where more than two-thirds of the available hydroxyl groups are acetylated. The solubility of cellulose acetate in acetone depends on the type of cellulose as well as on the extent of esterification, but it is not possible to produce an acetate which is completely soluble in acetone merely by interrupting the esterification at any stage.

Deripasko (*Cellulose Chem.*, 1931, 12, 254) has found that only acetates with acetic acid contents between 60 and 49% are soluble in acetone. A series of acetates with acetic acid contents varying from 60 to 57.5% was prepared and only acetates containing 57.4 to 57.8% were found soluble in ethyl acetate. Acetates containing 57% acetic acid were often found to be soluble both in chloroform and acetone.

From the above discussions it appears that the term "di-acetate" has been used in a very loose sense, as the lowest acetic acid content obtained, does not, as a rule, go below 51% (Miles' process) and goes as high as 58%, while theoretically di-acetate should contain as low as 48.8% of acetic acid content. Yarsley obtained 53%, whilst Hess *et al.* after repeated fractionation of acetone-soluble secondary acetate narrowed down the acetic acid content to 51-53% but not to 48.8% as required theoretically. Barnett (*loc. cit*) obtained a di-acetate having 48.8% of acetic acid content, but this acetate was mentioned as a fine white powder, soluble both in acetone and in chloroform, whilst according to other workers, di-acetate should be a white, fibrous mass, having its solubility only in acetone.

The absence of convincing data on this score, substantiated by their own experimental results, led the X-ray analysts to believe the acetone-soluble di-acetates to be a mixture of tri-acetate with varying proportions of unchanged cellulose, although this belief was hotly contested by workers in this line.

It appears from the works of the investigators, mentioned above, that they have overlooked the formation of a series of intermediate products, soluble both in chloroform and in acetone, in between the chloroform-soluble tri-acetate and acetone-soluble di-acetate which invariably occur during the process of the formation of cellulose acetates. The influence of the acetyl content or % acetic acid content was carefully examined by Coltof (*J. Soc. Chem. Ind.*, 1937, 56, 363). The conditions of preparation were varied to obtain a series of secondary acetates with decreasing acetyl content. These amount to 62.5% for the tri-acetate and 48.3% for the di-acetate calculated on the basis of % weight of acetic acid.

TABLE I  
*Cellulose acetate.*

Acetic acid content.	Solubility at room temp. in			Acetic acid content.	Solubility at room temp. in		
	CHCl <sub>3</sub> .	acetone.	ethyl acetate.		CHCl <sub>3</sub> .	acetone.	ethyl acetate.
60.0%	5	0	0	55.5%	4	5	4
58.9	5	2	—	54.5	3-4	5	—
58.5	5	3	—	54.0	3-4	5	3
57.2	5	4	2	52.8	3	5	2
56.8	5	5	—	46.0	0	2	—
56.0	5	5	—				

\*The fig. 5 denotes complete dissolution, the fig. zero, complete insolubility

It is evident that the relation between the dispersing and swelling action must increase with decreasing acetyl content.

The present author in a series of investigations has noted that in the preparation of cellulose acetates, during the first stage of acetylation, an acetate, soluble only in chloroform, is produced, which has an acetic acid content near about 62.5% as theoretically required for primary or tri-acetate. This acetate during the process of further reaction passes through several intermediate stages, where intermediate products are formed, which are soluble both in chloroform and in acetone to a varying degree till it reaches a stage where an acetate, soluble only in acetone and having acetic acid content of 48.8% (approx.) as theoretically required for di-acetate, is produced. If reaction is carried still further, the resultant acetate becomes progressively insoluble in acetone, acetic acid content having gone down below 48.8% (Tables II, III and IV).

The above course of reaction has been found to be a common feature in all the experiments undertaken under a given condition of a certain proportion of cellulose and acetylating mixture and temperature, but independent of the % catalyst (H<sub>2</sub>SO<sub>4</sub> of *d* 1.84). Contrary to previous observations, it has been observed that the increase of H<sub>2</sub>SO<sub>4</sub> up to 20.2% as a catalyst has no adverse effect on acetylation so far as the acetyl content of the product is concerned (Tables II-IV).

It has also been found that the hydrolysis of primary acetates (tri-) into secondary (di-) acetates can be brought about even without the presence of dilute acetic acid or water. The only difference observed between the one hydrolysed in the usual way and the other unhydrolysed, is longer hours required by the latter to give the same product or products. Besides this, no basic difference in the composition of the products or their solubility in different solvents has been observed (Table IV).

In the tables various degrees of solubility have been denoted by the following :

I. S. = insoluble ; P. S. = partly soluble ; M. S. = moderately soluble ; R. S. = readily soluble ; S = soluble ; C. S. = completely soluble ; A. S. = apparently soluble ; L. S. = less soluble ; P = plastic.

### E X P E R I M E N T A L

All the experiments were conducted under the following conditions :

(i). The proportion of cellulose and acetylating mixture was kept as C : Ac : An = 1 : 5 : 4, where C = cellulose, Ac = glacial acetic acid, An = acetic anhydride.

(ii). Temperature was kept the same viz., at 25° for the first hour, at 30° for the second hour, at 35° for the third, 40° for the fourth, at 40-45° for the fifth and 45° for the 6th and all subsequent hours, till it was kept for overnight. After that the temperature was further raised to 50° during the period of hydrolysis and kept there at that temperature until it was kept again for overnight.

(iii). Period of reaction was maintained the same as far as possible in order to ensure uniform result (see the tables).

(iv). Percentage of catalyst ( $\text{H}_2\text{SO}_4$ ,  $d$  1.84) used was varied within wide limits (from 11.0 to 20.2) but excepting a variation observed in the viscosity of the solution (solution was more viscous where less percentage of  $\text{H}_2\text{SO}_4$  was used), no basic difference in the chemical composition of the resultant acetate has been found out (Tables II--IV).

TABLE II

No. of expt.	No. of sample.	$\text{H}_2\text{SO}_4$ (catalyst).	Duration of reaction (total hrs.)	Solubility at room temp. in chloroform. acetone.		Acetic acid content.
3.	1	14.7%	6	M. S.	I. S.	62.4%.
	2	—	8	S.	„	62.4
4.	1	16.6	6	M.S.	I.S.	62.4
	2	—	8	S.	„	62.4
5	1	18.4	4	M.S.	I.S.	62.4
	2	—	6	S.	„	62.4
	3	—	8	R.S.	Swelling & P.S.	61.2
6.	1	20.2	6	S.	I.S.	62.4
	2	—	8	R.S.	Swelling & P.S.	61.2

TABLE III

No. of expt.	No. of sample.	H <sub>2</sub> SO <sub>4</sub> (catalyst).	Duration of reaction (total hrs.).	Period of hydrolysis (total hrs.).	Solubility at room temp. in		Acetic acid content.
					chloroform.	acetone.	
1.	1	11.0%	27 0	3.5	S.	C.S.	55.2%
2.	1	12.9	26.5	2.0	C.S.	"	56.4
	2	—	48.0	15.5	I.S.	"	50.4
3.	1	14.7	23.5	Nil	C.S.	A.S.	60.0
	2	—	25.0	1.0	"	S. but not readily	58.8
	3	—	26.0	2.0	"	B.S.	57.6
	4	—	26.5	2.5	"	"	57.6
	5	—	28.0	4.0	L.S.	"	55.2
	6	—	30.5	6.5	P.	C.S.	54.0
	7	—	31.0	7.0	"	"	54.0
	8	—	47.0	23.0	I.S.	"	49.2
	9	—	48.0	24.0	"	P.S.	48.0
	10	—	54.5	30.5	"	P.	47.4
	11	—	71.0	47.0	"	I.S.	45.6
	12	—	72.0	48.0	"	"	43.2
4.	1	16.6	25	Nil	C.S.	A.S.	61.2
	2	—	27	1.0	"	S.	58.8
5.	1	18.4	24.0	Nil	"	A.S.	61.2
	2	—	26.0	1.5	"	S.	57.6
	3	—	28.0	3.5	L.S.	C.S.	55.2
	4	—	32.0	7.5	P.	"	54.0
	5	—	48.0	23.5	I.	"	50.4
	6	—	53.0	28.5	"	"	49.2
6.	1	20.2	24.0	Nil	C.S.	S.	58.88
	2	—	26.0	1.5	L.S.	C.S.	57.6
	3	—	28.0	3.5	P.	"	54.0
	4	—	30.0	5.5	I.S.	"	52.8
	5	—	32.0	7.5	"	"	52.4
	6	—	48.0	23.5	"	P.	46.8
	7	—	55.0	30.5	"	I.S.	44.4

\* After the addition of 65% acetic acid.

In all the experiments, Indian cotton having  $\alpha$ -cellulose content of 99.5% was used. For the determination of acetic acid content the saponification method of Hess was followed ("Chemie der Cellulose", p. 415).

TABLE IV

No. of expt.	No. of sample.	H <sub>2</sub> SO <sub>4</sub> (catalyst).	Duration of reaction (total hrs.)	Period of hydrolysis (total hrs)	Solubility at room temp, in		Acetic acid.
					CHCl <sub>3</sub> .	acetone.	
3.	1	14.7%	23.5	Nil	C.S.	A.S.	60.0%
	2	—	47.0	23.5	P.	C.S.	54.0
	3	—	72.0	48.5	I.S.	P.S.	48.0
4.	1	16.6	27	Nil	C.S.	S not readily	58.8
	2	—	48	21.0	..	C.S.	55.0
	3	—	52	25.0	P.	..	52.8
	4	—	55	28.0	I.S.	..	51.6
	5	—	96	69.0	..	I.S.	44.4
	6	—	102	75.0	..	..	43.2
5.	1	18.4%	24	Nil	C.S.	A.S.	61.2
	2	—	26	2.0	..	S. but not readily	58.8
	3	—	28	4.0	..	..	58.8
	4	—	32	8.0	..	R.S.	57.6
	5	—	48	24.0	P.	C.S.	52.8
	6	—	53	29.0	I.S.	..	51.6
6.	1	20.2	24.0	Nil	C.S.	S.	58.8
	2	—	28.0	4.0	I.S.	C.S.	56.4
	3	—	32.0	8.0	I.S.	..	52.8
	4	—	48.0	24.0	..	..	50.4
	5	—	55.0	31.0	..	..	48.8

\* Without the addition of dil. acetic acid or water.

#### Procedure.

Cellulose in the form of bleached cotton (50 g.) was added gradually to the acetylating mixture consisting of glacial acetic acid (250 c. c.), acetic anhydride (200 c. c.), H<sub>2</sub>SO<sub>4</sub> (3.5 to 5.5 c. c.) previously cooled to about 20° taking care that the temperature did not rise above 25° (by cooling). After some time, the mass became pasty when the temperature was raised to 30° and kept at 30-35° till the mass became viscous. After some time temperature was raised to 45° and kept there till it became less viscous and transparent.

After 8 hours (the required reaction period) a test precipitate, washed to neutrality and dried, showed complete solubility in chloroform but complete insolubility in acetone (primary or tri-acetate). At this stage, it was kept overnight at room temperature. Next morning (about 24 hours) a test precipitate, washed to neutrality and dried, was found to be completely soluble in chloroform and apparently soluble in acetone. At this stage, the solution was hydrolysed with 65% acetic acid at 45-50°. After the hydrolysis had proceeded for a sufficient length of time the test precipitate was found completely soluble both in chloroform and in acetone (25-28

hours). Next a stage was reached when the precipitate became soluble only in acetone and not in chloroform (about 48 hours), when the acetic acid content of the acetate was near about 48.8% (theoretically required by di-acetate ; sample 2 in Expt. No. 2, samples 8 and 9 in Expt. No. 3, samples 5 and 6 in Expt. No. 5 in Table III and sample 3 in Expt. No. 3, sample 4 in Expt. No. 4, sample 6 in Expt. No. 5, and samples 4 and 5 in Expt. No. 6, in Table IV).

When hydrolysis was carried out still further beyond 48.8%, the acetate showed progressive insolubility even in acetone and a stage was reached when it became completely insoluble (samples 10, 11, and 12 in Expt. No. 3, samples 6 and 7 in Expt. 6. Table III, samples 5 and 6 in Expt No. 4, Table IV).

### DISCUSSION

A perusal of the various important methods of acetylation, adopted by Miles, Dreyfus, Yarsley and others will show that these authors have used different percentages of  $H_2SO_4$  as catalyst as shown below.

TABLE V

Authors.	% $H_2SO_4$ used.	Types of acetates produced.
1. Miles	5.5 to 16.5	Chloroform-soluble primary acetate in the beginning. Acetone-soluble secondary acetate on hydrolysis with 50% acetic acid.
2. Dreyfus	10.0 to 15.0	Chloroform-soluble primary acetate in the beginning. Acetone-soluble secondary acetate on hydrolysis with water alone.
3. Yarsley	10.0 to 15.0	Acetone-soluble primary acetate. Acetone-soluble secondary acetate on hydrolysis with 50% acetic acid.
4. Goswami & Choudhury*	1.8 to 8.0	Chloroform-soluble primary acetate. Acetone-soluble secondary acetate on hydrolysis with 50% acetic acid.
5. Do.	15.0 to 18.4	Powdery acetylated product insoluble in chloroform and acetone.

\* *J. Indian Chem. Soc. Ind. & News Ed.*, 1946, 9, 145.

But in a series of experiments, undertaken during the present investigations the author has found that the use of much higher percentage of  $\text{H}_2\text{SO}_4$  than hitherto employed (16.6, 18.4 and 20.2%) produces no adverse effect on the progress of acetylation. On the contrary, the acetates produced show exactly the similar solubility and practically the same acetic acid content as those formed by the use of lower percentage of  $\text{H}_2\text{SO}_4$  (Tables III and IV).

The process of hydrolysis *i.e.* the addition of either dilute acetic acid or water alone to bring about the degradation of primary acetate into secondary acetate to impart into the resultant product, the property of dispersion in acetone to a varying degree is well recognised and well established. Chemically speaking, hydrolysis brings down the acetic acid content of the primary acetate to a lower figure, making the acetate with lower acetic acid content fall in line within the range where the secondary acetate is soluble both in chloroform and acetone, soluble only in acetone and finally insoluble even in acetone, if the hydrolysis is allowed to have its course.

In almost all the known methods of preparation of secondary acetates, this process is followed universally. Even Yarsley (*loc cit.*), who claimed to have prepared an acetone-soluble primary acetate, had adopted hydrolysis with 50% acetic acid solution to obtain secondary acetate soluble in acetone.

The present author has found that the addition of either dilute acetic acid or water during the period of hydrolysis is not an essential factor for conversion of the primary into secondary acetates. The lowering down of the acetic acid content takes place even without the addition of water, the only factor affecting the whole process being the longer period required by this unhydrolysed primary acetate than that required by the primary acetate hydrolysed with dilute acetic acid (65% used by the author, vide Table IV).

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# SUPERSATURATION LIMITS OF SOLUTIONS. PART IV. THE EFFECT OF HEATING ON THE LIMITS OF SUPERSATURATION

BY RAM GOPAL

The effect of heating on the limits of supersaturation of aqueous solutions of a number of substances has been investigated. Heating, in general, stabilises solutions against spontaneous crystallisation; but solutions of KCl, KBr, KI and  $\text{KNO}_3$  etc., exhibit a very small or negligible heating effect. An explanation to the above anomaly is suggested by considering the concentration ( $c$ ) of the solute and viscosity ( $\eta$  or  $1/\eta = \phi$ ) of the medium. Roughly speaking, if the  $c\phi$  values for any solution are greater than 80, the heating effect is negligible.

Certain marked exceptions to the  $c\phi$  rule are noticed, specially in organic solutes and ammonium salts. These are accounted for by the low mutual affinity among the molecules of the solutes.

In previous communications the author (*J. Indian Chem. Soc.*, 1943, 20, 187; 1944, 21, 104) has observed that, in general,  $T_s - T$  (where  $T_s$  denotes the saturation temperature and  $T$ , the temperature of spontaneous crystallisation of a solution) increases with number and degree of heating. Several workers (Schaum, *Z. physikal. Chem.*, 1898, 25, 722; Schaum and Schoenbeck, *Ann. Physik*, 1902, 8, 655; Füchtbauer, *Z. physikal. Chem.*, 1904, 48, 549; Young and Burke, (*J. Amer. Chem. Soc.*, 1907, 29, 329; Issac, *J. Chem. Soc.*, 1908, 93, 384; Marcelin, *Compt. rend.*, 1910, 148, 631; Othmer, *Z. anorg. Chem.*, 1915, 91, 209; Kornfeld, *Monatsh.*, 1916, 37, 609; Hinshelwood and Hartley, *Phil. Mag.*, 1922, 43, 78; Schaum and Riffert, *Z. anorg. Chem.*, 1922, 190, 241; Richards, *J. Amer. Chem. Soc.*, 1932, 54, 479; Richards, Kirkpatrick and Hutz, *ibid.*, 1936, 58, 2243) have studied this problem but nearly all of them have confined themselves to the study of crystallisation of organic melts under prolonged heating. Their results appear to show that prolonged heating, in general, increases the limit of undercooling. However, a detailed study of solutions on these lines is almost lacking. It appears therefore desirable to study solutions from this viewpoint in order to collect data which will elucidate this anomalous behaviour (i.e. negligible effect of preheating on the limits of supersaturation of the solutions of  $\text{KNO}_3$ , KBr, KI etc.).

## EXPERIMENTAL

Sealed tubes containing solutions of different substances at some known saturation temperature ( $T_s$ ) were prepared in the same way as described in a previous communication (*loc. cit.*, 1943) and were heated in a beaker of water at  $80^\circ$  to  $90^\circ$  for various periods of time. They were shaken with hand vigorously from time to time as no suitable equipment could be conveniently fitted up for shaking them continuously while heating. The temperature of spontaneous crystallisation ( $T$ ) was determined in the usual manner. Results for typical substances of the two groups are given in Table I.



TABLE I

(Hours of heating are given in brackets ; \* denotes that crystallisation did not occur down to this temperature.)

G R O U P I.			
1. Potassium iodide.		2. Potassium bromide.	
$T_s$ .	$T$ .	$T_s$ .	$T$ .
80	64.6 (2), 64.4(5), 63.6 (11), 63.8 (14).	80	62.0 (8), 62.2 (10), 62.5 (16).
68	49.0 (2), 48.8 (11), 49.0 (14).	75	58.4 (8), 58.5 (10), 58.4 (16).
60	44.6 (2), 44.0 (5), 43.8 (11), 44.4 (11).	58	41.6 (2), 41.6 (11), 40.0 (16).
55 (?)	44.6 (2), 45.0 (5), 44.0 (11), 44.0 (14).	50	34.0 (6), 33.8 (16), 33.8 (20).
50	34.2 (2), 33.8 (5), 33.6 (11), 33.2 (14).	45	28.4 (6), 28.0 (10), 23.0 (16).
3. Potassium nitrate.		4. Sodium nitrate.	
75	60.2 (3), 61.0 (6), 60.0 (12).	70	57.2 (3), 57.0 (9), 57.4 (15).
70	55.0 (3), 55.6 (6), 56.0 (12).	65	51.2 (6), 52.0 (10), 51.0 (12).
60	47.0 (3), 46.8 (6), 46.0 (12).	60	45.2 (6), 44.0 (10), 44.0 (12).
50	36.2 (3), 36.0 (6), 35.4 (12).	50	3.8 (6), 37.2 (10), 36.0 (12), 35.6 (16).
45	32.0 (3), 31.4 (6), 31.0 (12).	45	30.6 (6), 30.0 (10), 30.2 (12).
G R O U P II.			
1. Barium nitrate.		2. Barium chloride.	
75	45.2 (1), 40.6 (2), 32.8 (3), *30.0 (5), *25.0 (6).	80	50.2 (2), 48.6 (4), 35.6 (6).
70	43.6 (1), 37.2 (2), *25.0 (3), *25.2 (5).	75	42.6 (2), 36.6 (4), *30.4 (6).
65	4.00 (1), 36.0 (2), *31.0 (3), 37.0 (4), *27.2 (6).	70	34.2 (2), *25.1 (4), *27.0 (6).
60	32.8 (1), 30.7 (2), *15.0 (4).	65	30.0 (2), 26.4 (4), *22.6 (6).
55	30.0 (1), 27.4 (2), 29.0 (4), *26.0 (5).	60	26.2 (2), *25.2 (4), *20.0 (6).
3. Potassium dichromate.		4. Potassium oxalate.	
75	42.2 (2), 38.0 (6), 61.2 (12), 55.0 (18).	80	40.2 (2), 30.2 (8), *26.0 (14).
65	45.0 (2), 40.2 (4), 30.0 (6), 31.2 (12), 25.8 (18).	75	37.4 (2), 32.2 (8), *26.0 (14).
55	30.8 (2), 40.2 (4), 30.0 (9), 20.0 (15).	70	30.2 (2), *26.0 (8), *24.0 (14).
50	26.6 (3), 23.0 (4), 20.4 (9), *18.0 (15).	65	28.4 (2), 20.8 (8), *16.0 (14).
40	32.0 (3), *19.6 (3), *15.0 (8).	60	*25.0 (2), *25 (8).
5. Thiourea.		6. Benzoic acid.	
70	44.0 (6), 37.6 (12), 34.2 (8).	75	53.2 (2), 35.0 (8), 53.2 (14).
65	45.6 (4), 33.0 (10), *30.0 (16).	70	45.0 (2), 40.0 (8), 37.8 (14).
60	32.2 (6), 39.2 (12), 25.8 (16).	65	42.0 (2), 40.2 (8), 36.0 (14).
55	28.4 (6), 23.2 (12), 20.0 (16).	60	34.0 (3), 30.6 (8), *25.0 (14).
50	35.2 (2), *29.0 (4), *25.4 (6).	55	33.2 (2), *28.0 (6), *24.2 (8), 32.8 (14).

From the examples cited in Table I and numerous other cases, which have been omitted here for the sake of brevity, it appears that the effect of heating in increasing the limits of supersaturation  $T_s - T$  is a very general phenomenon as has been observed in the case of organic melts by other workers (*loc. cit.*) and that only a few isolated cases show a small or negligible heating effect. The complete results of the investigation are summarised in Table II.

TABLE II

Substances showing a very small or negligible heating effect.

KCl\*, KBr, KI, NaNO<sub>3</sub>,  
KNO<sub>3</sub>, KClO<sub>4</sub>.

Substances with considerable heating effect.

Ba(NO<sub>3</sub>)<sub>2</sub>, BaCl<sub>2</sub>, KIO<sub>3</sub>, K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>, KClO<sub>3</sub>, KBrO<sub>3</sub>,  
K<sub>4</sub>Fe(CN)<sub>6</sub>, K<sub>3</sub>Fe(CN)<sub>6</sub>, NH<sub>4</sub>Cl, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, K<sub>2</sub>C<sub>2</sub>O<sub>4</sub>,  
(NH<sub>4</sub>)<sub>2</sub>C<sub>2</sub>O<sub>4</sub>, H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>, CO(NH<sub>2</sub>)<sub>2</sub>, CS(NH<sub>2</sub>)<sub>2</sub>,  
C<sub>6</sub>H<sub>5</sub>.COOH, NH<sub>4</sub>NO<sub>3</sub>\*\*, KCNS etc. etc.

\* Heating effect is appreciable in some tubes.

\*\* " " appears negligible specially at higher  $T_h$ .

## DISCUSSION

According to Hinshelwood and Hartley (*loc. cit.*) the heating effect is due to decrease in the catalytic activity of the colloidal dust particles\* which are derived from air. These particles are considered to be surrounded by an orientated adsorbed layer. This system acts as a fragment of a pure crystal in initiating spontaneous crystallisation. If large enough, the system is active immediately, if not, a series of fortunate chances are required in order that a crystal of necessary size may be formed. The degree of dispersion of the active colloidal particles is supposed to change irreversibly with preheating, time and other experimental conditions. Recent developments of this theory have been proposed by Richards and his co-workers (*loc. cit.*) to suit their experimental observations. For our purpose, however, only the hypothesis of Hinshelwood and Hartley, coupled with the molecular kinetic conceptions of de Coppet and G. Tammann about the formation of an active crystalline nucleus, appears to be more suitable and general and hence an attempt has been made to explain the different behaviours of the two classes of solutes mentioned above on these grounds.

\* A very convincing and direct experimental evidence in favour of the dust particle theory is found in the filtration effects on the spontaneous crystallisation of supercooled systems. This aspect of the problem has been investigated by Jaffé (*Z. physikal. Chem.*, 1903, 48, 585), Fichtbauer (*ibid.*, 1904, 48, 549), Meyer and Pfaff (*Z. anorg. Chem.*, 1934, 217, 257; 1935, 222, 882; 1935, 224, 304) and by Tammann and Buchner (*ibid.*, 1935, 222, 870). Filtration which removes dust particles, has been shown to stabilise supercooled systems against the chances of spontaneous crystallisation.

According to the well known kinetic molecular hypothesis, the formation of a crystalline nucleus is a probability phenomenon and a nucleus comes into stable existence when the lattice forming units collide in a sufficient number so as to produce a particle big enough to be stable at any particular temperature. This process will be aided by the dust particles which might act as adsorbents or simple heat carriers in the inelastic molecular collision or in some other mysterious fashion not yet clearly understood. The probability of formation of a crystalline nucleus cannot be exactly defined, nevertheless, it is possible to state qualitatively that it will be greater, (i) greater the concentration of the solute, (ii) greater the concentration of the dust particles or inductor, (iii) greater the volume of the system employed, (iv) greater the duration of the experiment i.e. smaller the rate of cooling, and (v) smaller the viscosity of the medium etc.

In order to obtain the relative values of the limits of supersaturation, conditions (iii) and (iv), i.e. the volume and the rate of cooling, have been kept similar in all the experiments and therefore their effect has been eliminated. Hence factors (i), (ii) and (v) will be effective in differentiating various systems.

The concentration of the dust particles (v) may be taken to be the same in all the cases in the beginning of the experiments and this will be gradually lowered in the process of heating and shaking. On the other hand, the concentration of the solute will remain constant depending only on its solubility. Due to lowering in the concentration of the inductor, the number of successful molecular collisions will go on diminishing in a definite time as the process of heating, shaking, crystallisation and redissolution is continued. If this probability is lowered to such an extent that no successful molecular collision occurs during the time of cooling, the temperature of spontaneous crystallisation will go on lowering with the amount of heating etc.

If the concentration of the solute is very high, however, the number of successful collision may still be very large even though some of the dust particles have been removed from the active field. It means that the time required for a successful collision may still be very small as compared to the rate of cooling. In other words, crystallisation should start at the previous temperature of spontaneous crystallisation after which the heating has been performed. Hence we see that although number or effectiveness of dust particles is being gradually reduced by heating and shaking etc., spontaneous crystallisation is yet possible at the original degree of supercooling if the concentration of the solute is very high. This appears to be the main cause of the anomaly referred to in Table II. Filtration appears to be more effective agency in this process, as after five to six operations a lowering in  $T$  has been noticed in solutions of  $\text{KNO}_3$  by Jaffé (*loc. cit.*) while they show negative effect in our case.

The viscosity  $\eta$  of the medium will oppose the molecular collisions or its reverse  $\phi$  (fluidity) will favour them. Hence fluidity like concentration will also control the molecular collisions. Their product may therefore be expected to

lead to an expression which may be closely related with the capacity of forming active centres in a system provided all collisions are successful. This is detailed in Table III in which the concentration  $c$  is expressed in g. mol. of solute per 100 g. of solvent<sup>†</sup>,  $\eta$  ( $1/\phi$ ) values are taken from an unpublished work on 'the viscosity of supersaturated solutions' by the author. The viscosity corresponds generally to the most probable temperature of the first spontaneous crystallisation and hence they are mostly intrapolated figures. The same temperature of saturation  $T_s$  (50°) has been considered in all the cases.

TABLE III

Solute.	$T_s - T^*$	$\eta$ † at 1st. $T$ .	$\frac{Sw_{100}}{M}$ = $c$ .	$\phi c$ (or $c/\eta$ )	Solute.	$T_s - T^*$	$\eta$ † at 1st. $T$ .	$\frac{Sw_{100}}{M}$ = $c$ .	$\phi c$ (or $c/\eta$ ).
KCl	19.5	0.00930	0.572	61.5	$K_2C_2O_4$	30.0	0.01900	0.2950	15.5
KBr	16.0	0.00876	0.696	79.4	$Ba(NO_3)_2$	18.0	0.00920	0.0655	8.9
KI	15.6	0.00980	1.000	102.0	$BaCl_2$	25.0	0.01450	0.2070	14.3
$KClO_4$	6.5	0.00600	0.0369	6.12	$NaClO_3$	14.0	0.03700	0.8970	24.2
$KNO_3$	13.0	0.01030	0.8530	82.7	Oxalic acid	15.0	0.01160	0.3992	34.4
$NaNO_3$	12.0	0.0258	0.8870	32.7	$KIO_3$	14.0	0.00800	0.0766	9.6
$KClO_3$	6.0	0.00645	0.1580	24.6	$HgCl_2$	23.2	0.00860	0.0420	4.9
$KBrO_3$	9.4	0.00670	0.0461	6.9	Succinic acid	2.00	0.01260	0.2067	16.5
$K_2Cr_2O_7$	12.0	0.00810	0.1190	14.7	Benzoic acid	17.8	0.00770	0.0066	0.84
$K_3Fe(CN)_6$	12.6	0.01340	0.1970	14.7	Salicylic acid	20.0	0.00790	0.0058	0.76
$K_4Fe(CN)_6$	20.0	0.01350	0.1160	8.9	Urea ( $T_s = 40^\circ$ )	15.0	0.02770 (Taimini)	2.5	110.0
$NH_4Cl$	20.0	0.00940	0.9530	101.4	Thiourea	11.2	0.00880	0.58	76.7
$Am_2SO_4$	20.0	0.02600	0.6360	24.4	$NH_4NO_3$	11.0	0.0290	4.56	157.0
$Am.oxalate$	12.4	0.00860	0.1050	12.3	KCNS	13.2	0.04300	3.30	76.7

Table III clearly shows that the value of  $c\phi$ , in cases where heating effect is very small or negligible, lies well above 30 except in  $KClO_4$  for which it is 6.1. Where heating effect is well marked, the values of  $c\phi$  lie, in general, below 20. Here again we meet with exceptions in ammonium salts and organic substances which, in spite of high  $c\phi$  values, show considerable heating effect. However, in spite of these exceptions the difference in the  $c\phi$  values of the two classes, in general, is so marked as to leave no doubt about the predominant effect of

† Concentration should be expressed by volume but as all other considerations are only highly approximate, it is perhaps superfluous to be too accurate in this case.

\*  $T$  denotes the first temperature of spontaneous crystallisation.

† Intrapolated to the required temperature if crystallisation occurs earlier as happens in most of the solutions of low viscosity.

concentration and viscosity on this phenomenon. Reviewing we can state qualitatively that if the concentration of the solute is very high and at the same time viscosity of the system is low, the heating effect will be very small or negligible (i. e.  $T_s - T$  should be approximately constant). On the other hand, if the viscosity of the system is high or concentration low or both, heating effect will be marked.

The exceptions remain to be explained. Uptil now we have been considering molecules and ions as simple neutral particles of matter, identical in all cases without any specific or individual characteristic of their own. When we come to concrete cases, this simplified view demands modification. Thus we cannot neglect the mutual affinity of molecules and ions, their different tendencies of being adsorbed on an interface and so on. If this attraction between the lattice forming units is sufficiently low or lattice formation is not feasible due to some energy or other considerations, it is possible that no crystalline centre may be formed even though  $c\phi$  values indicate a large probability of molecular impacts. In other words, it shows that under these circumstances the probability of *successful* molecular collision is very small inspite of large *unsuccessful* molecular encounters. The low mutual affinity among the molecules of the ammonium salts and among those of organic substances is shown by their easy subliming nature at low temperatures and their low melting points. According to Jaeger (*Z. anorg. Chem.*, 1917, 101, 1) the surface energy values  $\sigma$ , which may be in some way related to the mutual attraction of the lattice forming units of organic melts, are comparatively much low to those of the melts of ordinary inorganic electrolytes. This low affinity appears to be mainly responsible for the anomaly in most cases.

The ionic or molecular size or volume may explain some of the anomalies. Ions of larger volume will be required in a smaller number for the formation of stable crystal nucleus as compared to those of a smaller size. This means a higher probability of crystal nucleus formation in the former than in the latter. It appears, however, premature to apply this condition to individual cases.

The case of  $\text{KClO}_4$  must be considered for the present an unexplained exception until some more light is thrown on the problem by further investigation. It may be suggested, however, that very low viscosity of its solutions may be to some extent responsible for this behaviour. But this explanation is obviously not enough.

The author is highly obliged to Dr. A. C. Chatterji for helpful criticism and valuable suggestions.

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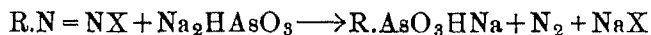
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# ORGANO-ARSENICALS. PART I. SOME NEW N-ISOCYCLIC AMIDOSULPHOPHENYLARSONIC ACIDS\*

BY PALLAVUR PARASURAMIYER KRISHNAN, BALKRISHNA HARIHAR IYER  
AND PRAPHULLA CHANDRA GUHA

Fifteen N-isocyclic amidosulphophenyl-4'-arsonic acids have been synthesised by the application of Bart's reaction to each of the three isomeric OH-, OMe-, NO<sub>2</sub>, CH<sub>3</sub>- and COOH- substituted N<sup>1</sup>-phenylsulphanilamides. The three N-nitrophenylamidosulphophenyl-4'-arsonic acids have been reduced to the corresponding aminoarsonic acids. N<sup>1</sup>-*o*- and N<sup>1</sup>-*m*-methoxyphenylsulphanilamides have been described.

The most satisfactory general method for the synthesis of aryl arsonic acids is by the application of Bart's reaction (D. R. P. 250264), where the diazo group is replaced by the AsO(OH)<sub>2</sub>- group in accordance with the following equation :



In the present investigation, eighteen N-isocyclic amidosulphophenyl-4'-arsonic acids of type (I) (vide Table I) have been synthesised, the first fifteen were prepared by the application of Bart's reaction to the appropriate N<sup>1</sup>-isocyclic sulphanilamides and the remaining three (16, 17, 18) by the reduction of the corresponding nitro derivatives (7, 8, 9) with ferrous sulphate and alkali.

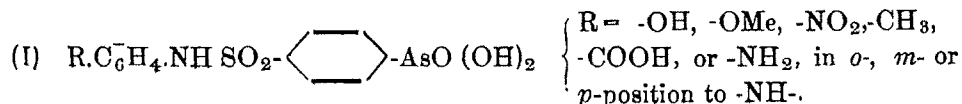


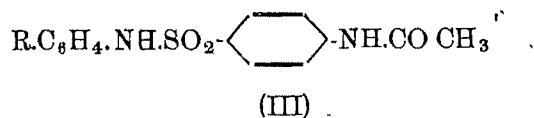
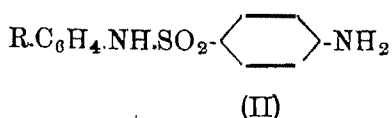
TABLE I

*Eighteen N-R''-sulphophenyl-4'-arsonic acids of type (I) where  
R''-stands for:*

(1) 2-Hydroxyphenylamido-	(10) 2-Methylphenylamido-
(2) 3- " " "	(11) 3- " " "
(3) 4- " " "	(12) 4- " " "
(4) 2-Methoxyphenylamido-	(13) 2-Carboxyphenylamido-
(5) 3- " " "	(14) 3- " " "
(6) 4- " " "	(15) 4- " " "
(7) 2-Nitrophenylamido-	(16) 2-Aminophenylamido-
(8) 3- " " "	(17) 3- " " "
(9) 4- " " "	(18) 4- " " "

\* A note on this work was published in *Science & Culture*, 1945-46, 11, 568.

Webster and Powers (*J. Amer. Chem. Soc.*, 1938, **60**, 1553) prepared N<sup>1</sup>-*o*-, *m*-, and *p*-hydroxyphenylsulphanilamides of type (II) by condensing *p*-acetaminobenzene sulphonylchloride with the respective aminophenols and hydrolysing the resulting N<sup>1</sup>-hydroxyphenyl-N<sup>4</sup>-acetylsulphanilamides of type (III) where R stands for -OH.



Northey (*Chem. Rev.*, 1940, **27**, 97) has mentioned N<sup>1</sup>-*o*-methoxyphenylsulphanilamide but details of its preparation have not been available. Therefore this compound (II, R=*o*-OMe) and its *meta*-isomer, which is described for the first time, have now been prepared by reacting *p*-acetaminobenzene sulphonyl chloride with *o*- and *m*-anisidines respectively and hydrolysing the acetyl derivatives thus obtained. Choudhury, Das-Gupta and Basu (*J. Indian Chem. Soc.*, 1937, **14**, 733) prepared the *p*-isomer in a similar manner using *p*-anisidine.

N<sup>1</sup>-*o*-, *m*- & *p*-Nitrophenylsulphanilamides have been prepared before (Webster and Powers, *loc. cit.* Bauer, *J. Amer. Chem. Soc.*, 1939, **61**, 613).

The three N<sup>1</sup>-methyl and N<sup>1</sup>-carboxyphenylsulphanilamides were prepared according to known methods (*cf.* Northey, *loc. cit.* Gelmo, *J. prakt. Chem.*, 1908, *ii*, **77**, 369; Kolloff, *J. Amer. Chem. Soc.*, 1938, **60**, 950; Bauer, *ibid.*, 1939, **61**, 613).

According to French Patent No. 624028 N<sup>1</sup>-2-carboxyphenylamidodisulphophenyl-4'-arsonic acid (No 13 of Table I) was prepared in 37% yield by the application of Scheller's reaction on N<sup>1</sup>-*o*-carboxyphenylsulphanilamide using AsCl<sub>3</sub> and a catalyst like CuCl. Oneto and Way (*J. Amer. Chem. Soc.*, 1941, **63**, 762) prepared this compound in 54% yield by condensing *p*-chlorosulphophenylarsonic acid with *o*-aminobenzoic acid. By the application of the Bart's reaction it has now been prepared in 50% yield.

The arsonic acids described here have no definite melting points. They are soluble in alkalis and carbonates but insoluble in common organic solvents and mineral acids.

## EXPERIMENTAL

Compounds 1 to 15, both inclusive (*vide* Table I), were prepared by the application of Bart's reaction to *o*-, *m*- and *p*-isomers of hydroxy-, methoxy-, nitro-, methyl-, and carboxyphenyl-sulphanilamides according to details given for compound (1) below.

*N*-2-*Hydroxyphenylamidodisulphophenyl-4'-arsonic acid*, (1).—*N*<sup>1</sup>-*o*-Hydroxyphenylsulphanilamide (13.2 g.), dissolved in 1 : 1 hydrochloric acid (33 c.c.), was diazotised with sodium nitrite (3.5 g.) in water (30 c.c.). The resulting diazonium solution was poured under cooling and stirring into a solution of sodium arsenite (9.6 g.) in water (100 c.c.) containing sodium hydroxide (10 g.) and heated on a water-bath till the evolution of nitrogen ceased. The liquid was then cooled and acidified with hydrochloric acid when the arsonic acid separated. It was filtered, washed with water and purified by dissolution in sodium carbonate solution and precipitation with acid, yield 7.5 g.

Compounds (16), (17) and (18) were obtained on reducing compound (7), (8) and (9) respectively with ferrous sulphate and alkali according to details given for compound (16) below.

*N*-2-*Aminophenylamidodisulphophenyl-4'-arsonic Acid*, (16).—Sodium hydroxide solution (10%, 110 c.c.) was added in small quantities at a time to an ice-cold solution of ferrous sulphate (30 g.) in water (75 c.c.) under stirring when the ferrous hydroxide separated in the form of a green mud. Compound No. 7 (6 g.), dissolved in sodium hydroxide solution (10%, 40 c.c.) was poured into the ferrous hydroxide mixture and shaken thoroughly during 15 minutes when the colour of the mud changed from green to brown indicating its conversion into ferric hydroxide. The mud was then filtered out and washed with water. When the combined filtrates were acidified with acetic acid, the product separated and was collected, washed and purified, yield 3 g.

*N*<sup>1</sup>-*o*-*Methoxyphenyl-N*<sup>4</sup>-*acetyl* sulph anilamide, (III, R = *o*-OMe).—To freshly distilled *o*-anisidine (10 g.), crude air-dried *p*-acetaminobenzene sulphonylchloride (10 g.) was gradually added with stirring. The mixture was then heated on a water-bath for half an hour and the mass, thus obtained, was ground with 1 : 1 hydrochloric acid when the product separated out. It was filtered, washed with water and crystallised from dilute alcohol, m. p. 204-205°, yield 11 g.

The yield improved when the condensation was carried out in presence of sodium acetate. To a suspension of *o*-anisidine (5 g.) in hot (75°) water (100 c.c.) containing anhydrous sodium acetate (3 g.), *p*-acetaminobenzene sulphonylchloride (10 g.) was gradually added with stirring. After half an hour the product separating was filtered, washed with water and crystallised as before, yield 12 g. (Found : C, 56.01 ; H, 4.95. C<sub>15</sub>H<sub>14</sub>O<sub>4</sub>N<sub>2</sub>S requires C, 56.26 ; H, 5.00 per cent).

*N*<sup>1</sup>-*o*-*Methoxyphenylsulphanilamide*, (II, R = *o*-OMe).—The above acetamino compound (12 g.) was refluxed with 1 : 1 hydrochloric acid (25 c.c.) till all the solid went into solution. The hydrochloride of the amine, which separated out on cooling, was collected, redissolved in minimum quantity of water and the solution basified with ammonia when the product precipitated out. This was filtered, washed, and crystallised from alcohol, m. p. 186°, yield 10.3 g. (Found : C, 55.93 ; H, 5.00. C<sub>13</sub>H<sub>14</sub>O<sub>3</sub>N<sub>2</sub>S requires C, 56.11 ; H, 5.04 per cent).



*N*<sup>1</sup>-*m*-Methoxyphenyl-*N*<sup>4</sup>-acetylsulphanilamide, (III, R=*m*-OMe).—To a suspension of *m*-anisidine (3 g) in hot water (100 c c) containing anhydrous sodium acetate (2 g.), *p*-acetaminobenzene sulphonylchloride (6 g.) was gradually added under stirring. After half an hour, the product which had separated was collected and crystallised from alcohol, m. p. 177-78°, yield 6 g. (Found : C, 55.98 ; H, 4.91. C<sub>15</sub>H<sub>16</sub>O<sub>4</sub>N<sub>2</sub>S requires C, 56.26 ; H, 5.00 per cent).

*N*<sup>1</sup>-*m*-Methoxyphenylsulphanilamide (II, R=*m*-OMe).—The above acetamino compound (12 g.) was hydrolysed with hydrochloric acid and the product isolated in the usual manner, m. p. 150° yield 10.4 g. (Found : C, 55.90 ; H, 4.98. C<sub>13</sub>H<sub>14</sub>O<sub>3</sub>N<sub>2</sub>S requires C, 56.11 ; H, 5.04 per cent)

The analytical data for the eighteen arsonic acids are given in Table II.

TABLE II

Compound No.	Formula.	% Arsenic Found.	% Arsenic Calc.	Compound No.	Formula.	% Arsenic Found.	% Arsenic Calc.
1.	C <sub>19</sub> H <sub>17</sub> O <sub>6</sub> NSAs	19.99	20.11	10.	C <sub>13</sub> H <sub>14</sub> O <sub>6</sub> NSAs	20.13	20.21
2.	"	19.94	20.11	11.	"	20.18	20.21
3.	"	19.87	20.11	12.	"	20.12	20.21
4.	C <sub>15</sub> H <sub>14</sub> O <sub>6</sub> NSAs	19.23	19.38	13.	C <sub>13</sub> H <sub>12</sub> O <sub>7</sub> NSAs	18.79	18.71
5.	"	19.30	19.38	14.	"	18.61	18.71
6.	"	19.17	19.35	15.	"	18.92	18.71
7.	C <sub>12</sub> H <sub>11</sub> O <sub>7</sub> N <sub>2</sub> SAAs	18.51	18.66	16.	C <sub>12</sub> H <sub>11</sub> O <sub>6</sub> N <sub>3</sub> SAAs	19.93	20.17
8.	"	18.49	18.66	17.	"	20.01	20.17
9.	"	18.41	18.66	18.	"	19.87	20.17

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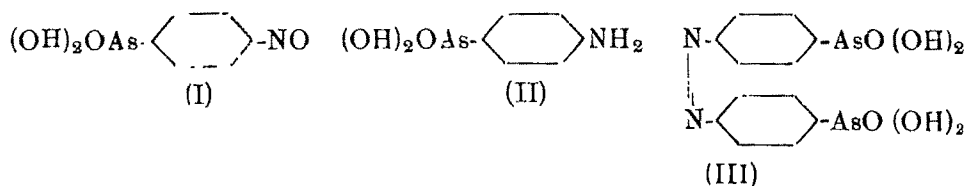
Received December 6, 1947.

## ORGANO-ARSENICALS. PART II. SOME NEW ARYL AZO-ARSONIC ACIDS \*

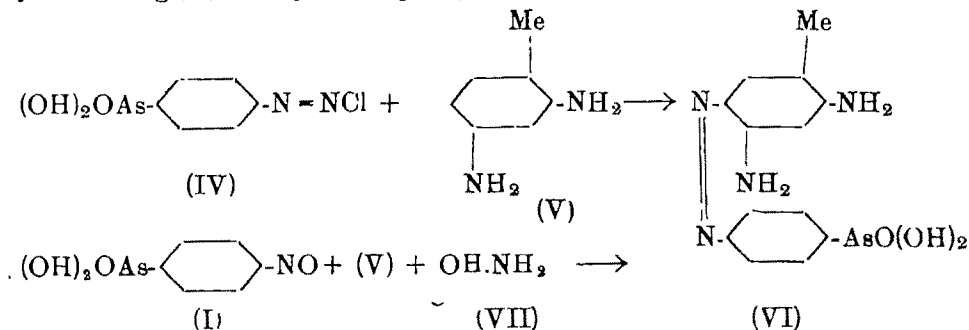
BY PALLAVUR PARASURAMIYER KRISHNAN, BALKRISHNA HARIHAR IYER  
AND PRAPHULLA CHANDRA GUHA

Fourteen aryl azo-arsonic acids, prepared by diazotising *p*-arsanilic acid and coupling with aromatic hydroxy, and amino compounds, as well as sulphonic acids, two by diazotising *o*- and *m*-arsanilic acids and coupling with methone and one by diazotising sulphanilamide and coupling with *p*-arsanilic acid, have been described.

Protozoal diseases like sleeping sickness have been treated on the one hand with azo dyes like trypan red and on the other, with organo-arsenicals like atoxyl. With a view to combining these two modes of treatment, a number of azo dyes containing arsenic have been synthesised, and patented (Aktien Gesellschaft für Anilin Fabrikation, D.R.P., 212018, 212304, 220063, 216223; Noelting, *Bull. Soc. chim.*, 1916, *iv*, 19, 361). The two methods employed for the synthesis of azo derivatives of *p*-arsanilic acid are: (a) by the condensation of *p*-nitrosophenylarsonic acid (I) with suitable aryl amines (Karrer, *Ber.*, 1912, 45, 2065) and (b) by diazotising *p*-arsanilic acid (II) and coupling with suitable components. Condensation of (I) with (II) gives azobenzene-4 : 4'-diarsonic acid (III) which is a dark powder, easily soluble in alkalis.



Benzene-azo-2 : 4-tolylenediamino-4'-arsonic acid (VI) is prepared either by coupling the diazonium salt (IV) of *p*-arsanilic acid with *m*-tolylenediamine (V) or by condensing (V) with *p*-nitrosophenylarsonic acid (I) and hydroxylamine (VII)



in alkaline solution (Ehrlich and Bertheim, *Ber.*, 1907, 40, 3297; D.R.P., 205449; E.P., 3929 of 1907; Benda, *Ber.*, 1911, 44, 3878, 3295, 3300).

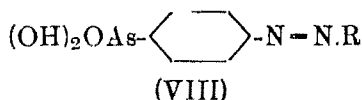
Barrowcliff, Pymann and Rewfy (*J. Chem. Soc.*, 1908, 93, 1899) have shown that the mono-azo derivatives are only slightly active towards trypanosomes. The azo-arsonic acid (VI) has been found to be more toxic than (III). It has

\* A note on this work was published in *Science & Culture*, 1945-46, 11, 567.

been observed that the poly-azo arsenical dyes have a greater trypanocidal action than the mono-azo dyes and are 2.5 times less toxic than atoxyl to the host (cf. Morgan, "Organic Compounds of Arsenic and Antimony", pp. 179-182).

Jacobs and Heidelberg (J. Amer. Chem. Soc., 1921, 43, 1646) and Berlingozzi (Annal. Chim. Appl., 1928, 18, 31, 333) have prepared a number of azo-arsenicals. Quite a number of patents have been taken on azo-arsenicals in general which indicates that this is a fruitful line for further research (cf. Friend, "A Text-Book of Inorganic Chemistry", Vol. XI, Part II, p. 231).

In the present investigation fourteen (1 to 14) mono-azo arsonic acids (vide Table I) of the type (VIII, where R stands for the coupling component less one hydrogen atom) have been prepared by method (b) cited above.



Iyer and Chakravarty (J. Indian Inst. Sci., 1934, 17A, 41) and Iyer (*ibid.*, 1938, 21A, 65) prepared a number of azo dyes by coupling methone (5 : 5-dimethyldihydroresorcin) with diazonium and tetrazonium salts. All the three aminophenylarsonic acids have now been diazotised and coupled with methone to give compounds (14), (15) and (16) (vide Table I).

TABLE I  
"A"-stands for arsonic acid.

Compound No	Aryl-azo arsonic acid.	Coupling component.
1.	4-Hydroxy-3-methylazobenzene-4'-A	<i>o</i> -Cresol
2.	4 " -2- " -4'-A	<i>m</i> -Cresol
3.	2 " -5- " -4'-A	<i>p</i> -Cresol
4.	2 : 4-Dihydroxyazobenzene-4'-A	Resorcinol
5.	2-Hydroxynaphthalene-3-azophenyl-4'-A	$\beta$ -Naphthol
6.	4-Hydroxy-3-carboxyazobenzene 4'-A	Salicylic acid
7.	4-Amino-3-carboxyazobenzene-4'-A	Anthranilic acid
8.	1-Aminonaphthalene-4-azophenyl-4'-A	$\alpha$ -Naphthylamine
9.	2-Aminonaphthalene-8- " 4'-A	$\beta$ -Naphthylamine
10.	2-Hydroxy-3 : 6-disulphonylnaphthyl-azophenyl-4'-A	2-Naphthol-3 : 6-disulphonic acid
11.	1-Amino-3 : 6 : 8-trisulphonyl-2-azophenyl naphthyl-4'-A	8-Aminonaphthalene-1 : 3 : 6-trisulphonic acid
12.	1-Amino-8-hydroxy-3 : 6-disulphonyl-7-azonaphthylphenyl-4'-A	1-Amino-8-hydroxy-naphthalene-3 : 6-disulphonic acid
13.	2-Hydroxy-6 : 8-disulphonyl-7-azonaphthylphenyl-4'-A	2-Naphthol-6 : 8-disulphonic acid
14.	2-Hydroxy-4-dimethyl-6-keto-3 : 4 : 5 : 6-tetrahydroazobenzene-4'-A	Methone
15.	2-Hydroxy-4-dimethyl-6-keto-3 : 4 : 5 : 6-tetrahydroazobenzene-8'-A	"
16.	2-Hydroxy-4-dimethyl-6-keto-3 : 4 : 5 : 6-tetrahydroazobenzene-2'-A	"
17.	4-Sulphonamido-2'-aminoazobenzene-5'-A	<i>p</i> -Arsanilic acid

When diazotised arsanilic acid is coupled with sulphanilamide in acid medium no product can be isolated. But when sulphanilamide is diazotised and coupled with arsanilic acid, the azo-arsenical (No. 17 of table) separates out neatly.

#### EXPERIMENTAL

Compounds (1) to (7), both inclusive and (14) were prepared by diazotising *p*-arsanilic acid and coupling in alkaline medium with the coupling component mentioned against each of them in Table I. Compounds (15) and (16) were prepared by diazotising *m*-amino- and *o*-amino-phenylarsonic acids respectively and coupling with methone. A typical experiment is detailed below.

*4-Hydroxy-3-methylazobenzene-4'-arsonic Acid*, (1).—Arsanilic acid (4.32 g.) dissolved in 1 : 1 hydrochloric acid (14 c. c.) was diazotised with sodium nitrite (1.4 g.) dissolved in water (14 c.c.) The clear diazonium solution was then poured into *o*-cresol (2.16 g.) dissolved in 10% sodium hydroxide solution (40 c.c.). The dark coloured solution thus obtained was acidified with dilute hydrochloric acid when an orange dye separated. It was filtered and washed with water. It is soluble in hot alcohol, slightly soluble in acetic acid, insoluble in water and ether. It was crystallised from alcohol, yield 4.5 g.

Compounds (8) and (9) were prepared according to the details given below using  $\alpha$ - and  $\beta$ -naphthylamines respectively.

*1-Aminonaphthalene-4-azophenyl-4'-arsonic Acid*, (8).—The diazonium solution from arsanilic acid (2.17 g.) was added under stirring to a well cooled solution of  $\alpha$ -naphthylamine (1.43 g.) in alcohol (50 c. c.) when an intensely coloured solution resulted. On adding an equal volume of water and leaving it overnight the dye was thrown out as a dark precipitate. It was filtered, washed with water and dried. It is soluble in acids, alkalis and alcohol, insoluble in water, yield 3.5 g.

Compounds (10), (11), (12) and (13) were obtained by coupling diazotised *p*-arsanilic acid with the respective sulphonic acid in alkaline medium and isolating the product as in the typical experiment detailed below.

*2-Hydroxy-3 : 6-disulphonylnaphthylazophenyl-4'-arsonic Acid*, (10).—The diazonium solution from arsanilic acid (2.17 g.) was slowly added with stirring to a well cooled solution of 2-naphthol-3 : 6-disulphonic acid (3 g.) dissolved in 10% sodium hydroxide solution (60 c. c.). The resulting solution was acidified and poured into excess of alcohol when the dye was thrown out as an orange-red precipitate. It was filtered, washed with alcohol and dried. It is soluble in alkalis, carbonates and water ; insoluble in alcohol, yield 2.7 g.

*4-Sulphonamido-2-aminoazobenzene-5'-arsonic Acid*, (17).—Sulphanilamide (1.7 g.) dissolved in 1 : 1 hydrochloric acid (8 c. c.) was diazotised with sodium nitrite (0.7 g.) in water (7 c. c.) and coupled with arsanilic acid (2.2 g.) dissolved in 10% sodium hydroxide solution (30 c. c.). After acidification and standing overnight, a red dye separated which was filtered, washed with water and dried, yield 2.3 g.

All the compounds, obtained in good yield, were purified either by crystallisation from alcohol or acetic acid or by dissolution in alkali and precipitation by acid. They had no melting point. The analytical data, excepting for compound (12), which could not be obtained pure enough for analysis, are given in Table II.

TABLE II

No.	Formula.	% Arsenic		No.	Formula.	% Arsenic	
		Found.	Calc.			Found.	Calc.
1.	$C_{13}H_{13}O_4N_4As$	22.09	22.32	9.	$C_{16}H_{14}O_3N_3As$	20.10	20.21
2.	$C_{13}H_{13}O_4N_2As$	22.19	22.32	10.	$C_{16}H_{13}O_{10}N_1S_2As$	14.03	14.10
3.	$C_{13}H_{13}O_4N_2As$	22.19	22.32	11.	$C_{16}H_{13}O_{10}N_2S_3As$	12.16	12.27
4.	$C_{12}H_{11}O_5N_2As$	21.97	22.13	12.	Not analysed		
5.	$C_{16}H_{13}O_4N_3As$	20.00	20.17	13.	$C_{16}H_{13}O_{10}N_2S_2As$	13.95	14.10
6.	$C_{13}H_{11}O_6N_2As$	20.31	20.48	14.	$C_{14}H_{17}O_5N_2As$	20.31	20.38
7.	$C_{13}H_{12}O_5N_3As$	20.49	20.55	15.	„	20.31	20.38
8.	$C_{16}H_{14}O_3N_3As$	19.99	20.21	16.	„	20.32	20.38
				17.	$C_{12}H_{13}O_5N_4SAs$	18.69	18.75

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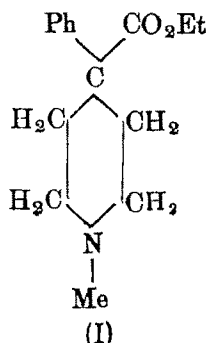
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## SYNTHESIS OF PIPERIDINE DERIVATIVES. PART I. SUBSTITUTED N-METHYL-4-PIPERIDOLS

By S. H. ZAHHEER, A. B. SEN AND G. S. SIDHU

Four different diethyl 1-methyl-2 : 6-diphenyl-4-alkyl (or aryl)-4-oxypiperidine-3 : 5-dicarboxylic esters have been synthesised by the action of the appropriate alkyl or aryl magnesium halide on diethyl 1-methyl-2 : 6-diphenyl-4-piperidone-3 : 5-dicarboxylate.

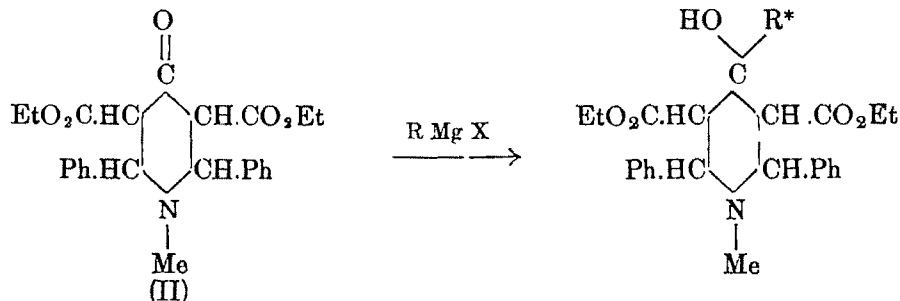
Considerable effort has been made in recent years for the synthesis of analgesics which do not possess the undesirable after-effects produced by morphine and atropine viz, the dryness of the mouth, increased heart-beat and blood-pressure and antagonisation of the acetylcholine set free at the nerve endings and lastly, drug addiction. Eisleb and Schaumann (*Deut. Med. Wochr.*, 1939, 65, 967 ; *Ber.*, 1941, 74, 1433) deserve the credit of preparing for the first time a compound "Dolantin" with such properties, which has found universal and extensive application. Dolantin is the hydrochloride of pethidine (ethyl 1-methyl-4-phenylpiperidine-4-carboxylate) (I). Synthesis of pethidine has also been later achieved by Bergel, Morrison and Rinderknecht (*J. Chem. Soc.*, 1944, 267) and by Walton and Green (*ibid.*, 1945, 316). This compound is a substituted piperidine.



The present work was undertaken with a view to preparing other substituted piperidines and to examine them for possible analgesic and antispasmodic properties.

The pharmacological interest attaching to piperidine derivatives has led several workers to investigate methods of synthesising compounds of this series. Cook and Barr (*J. Chem. Soc.*, 1945, 438) obtained N-alkyl-substituted piperidines by the hydrogenation of  $\gamma$ -cyano esters in alcoholic solution with copper chromite. Koelsch (*J. Amer. Chem. Soc.*, 1943, 65, 2093, 2458, 2459, 2460) has also effected a number of intermediate preparations of N-alkyl  $\alpha$ -piperidones. Cook and Reed (*J. Chem. Soc.*, 1945, 399) obtained 4-piperidone derivatives from *bis*- $\gamma$ -cyanoethyl-methylamine which were later converted into more complex heterocyclic systems. Anker, Cook and Heilbron (*ibid.*, 1945, 917) prepared a N-phenyl analogue of Dolantin and other analogous compounds with oxygenated groupings in the N-phenyl residue. Cook and Anker (*ibid.*, 1946, 58) have further extended this work to the synthesis of pyridocoumarins and dimethylpyran derivatives.

A very simple method for the preparation of compounds of Pethidine type has been developed by the present authors. It consists of the action of different alkyl and aryl magnesium halides on substituted  $\gamma$ -piperidones, obtained by the Mannich reaction. In this paper the synthesis of four different diethyl 1-methyl-2 : 6-diphenyl-4-alkyl (or aryl)-4-oxypiperidine-3 : 5-dicarboxylates is described. They have been obtained by the action of the appropriate alkyl (or aryl) magnesium halides on diethyl 1-methyl-2 : 6-diphenylpiperidone-3 : 5-dicarboxylate (II).



\*(III). R =  $-\text{CH}_2\text{CH}_3$

(IV). R =  $-\text{CH}_2\text{CH}_2\text{CH}_3$

(V). R =  $-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$

(VI). R =  $-\text{C}_6\text{H}_5$

The results of the investigation of the physiological properties of these compounds will be communicated later.

## EXPERIMENTAL

*Diethyl 1-methyl-2 : 6-diphenyl-4-piperidone-3 : 5-dicarboxylate* (II) was prepared essentially by the method of Petrenko-Kritschenko and Lewin (*Ber.*, 1907, **40**, 2884 ; 1909, **42**, 3684) but with modifications which led to easier isolation of the end product.

To a mixture of ethyl acetone dicarboxylate (13.5 g., 0.67 mole) and benzaldehyde (14 g., 0.137 mole), cooled in ice, were added at an interval of about 15 minutes, 15 c. c. of a 33% ice-cold alcoholic solution of methylamine (4 g., 0.135 mole) and left overnight in the refrigerator. After twelve hours' standing at room temperature, it was diluted with alcohol (1 : 1) and saturated with hydrochloric acid gas under cooling. The precipitated hydrochloride of the piperidone (II) was collected, washed with ice-cold alcohol and covered with an excess of ammonia. Next day the liberated piperidone (II) was filtered off, dried and recrystallised from hot alcohol, m. p.  $86^\circ$ , yield 49% ; hydrochloride, m. p.  $196^\circ$ .

*Diethyl 1-Methyl-2 : 6-diphenyl-4-ethyl-4-oxypiperidine-3 : 5-dicarboxylate* (III).—The Grignard reagent from ethyl iodide (1.2 g., 0.0075 mole) and magnesium (0.18 g., 0.0075 mole) was prepared as usual in 25 c. c. anhydrous ether in a three-necked flask fitted with a reflux condenser, a mechanical stirrer and a

dropping funnel, nitrogen being admitted through a side tube in the flask. After 10 minutes' cooling in ice, vacuum dried piperidone (II, 3.1 g., 0.0075 mole), dissolved in 30 c. c. of dry ether was added in rapid drops from the dropping funnel. A pale yellow precipitate separated immediately and coated the sides of the flask. After half an hour's refluxing of the ether on a water-bath, the contents were poured on to crushed ice and acidified with dilute sulphuric acid (Congo red). The ethereal layer was decanted off and the precipitate collected, and recrystallised from boiling alcohol in small white needles, m.p. 163°, yield 3 g. (90% of theory). It is also soluble in chloroform. (Found : N, 2.82.  $C_{26}H_{33}O_5N$  requires N, 3.19 per cent).

The ethereal layer on evaporation after drying over anhydrous sodium sulphate left no residue.

*Diethyl 1-methyl-2 : 6-diphenyl-4-n-propyl-4-oxypiperidine-3 : 5-dicarboxylate* (IV) was obtained by the action of *n*-propyl magnesium bromide (from Mg, 0.18 g., 0.0075 mole and *n*-propyl bromide, 1 g., 0.0075 mole in 25 c.c. dry ether in an atmosphere of nitrogen) on piperidone (II, 3 g., 0.0075 mole), dissolved in dry ether, as described under compound (III) and recrystallised from boiling alcohol in small white needles, m.p. 186-87°, yield 3.1 g. (90% of theory). (Found : N, 2.68  $C_{27}H_{35}O_5N$  requires N, 3.09 per cent).

The ethereal layer after drying and evaporation left no residue in this case also

*Diethyl 1-methyl-2 : 6-diphenyl-4-n-butyl-4-oxypiperidine-3 : 5-dicarboxylate* (V) was prepared by the action of *n*-butyl magnesium bromide on piperidone (II, 3 g.), dissolved in dry ether, as under (III), and recrystallised from boiling alcohol in small white needles, m. p. 191-92°, yield 3.3 g. (94% of theory). (Found : N, 2.71.  $C_{28}H_{37}O_5N$  requires N, 3.00 per cent).

In this case also the ethereal layer on evaporation left no residue.

*Diethyl 1-methyl-2 : 6-diphenyl-4-phenyl-4-oxypiperidine-3 : 5-dicarboxylate* (VI) was prepared by the action of phenyl magnesium bromide (from 0.36 g. of Mg and 2.4 g. of bromobenzene, in 100 c. c. dry ether in an atmosphere of nitrogen) on piperidone (II, 6 g.), dissolved in dry ether as described under compound (III). A small quantity of diphenyl was also formed and was recovered from the ethereal layer. The precipitate of compound (VI), formed on decomposing the Grignard-complex by sulphuric acid, was therefore washed with 50 c.c. of ether to remove any diphenyl

The compound (VI) is sparingly soluble in boiling ethyl alcohol and almost insoluble in ether, acetone, chloroform, petroleum ether, benzene and toluene. It was recrystallised from boiling methyl alcohol (30 c.c. methyl alcohol for 1 g. of the compound). It was quite pure when washed once with ether, followed by a small quantity of boiling methyl or ethyl alcohol, m. p. 186°, yield 6.5 g. (90% of theory) (Found : N, 2.63.  $C_{30}H_{33}O_5N$  requires N, 2.94 per cent).

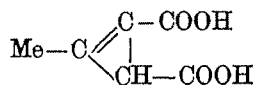


## RESOLUTION OF $\alpha\gamma$ -DIPHENYLGLUTACONIC ACID

BY G. M. KELKAR, N. L. PHALNIKAR AND B. V. BRIDE

$\alpha\gamma$ -Diphenylglutaconic acid has been resolved into *d*- and *l*-forms by the fractional precipitation of its strychnine salt. The *dextro*-form has not been obtained in an optically pure condition. The acids could not be racemised by heating with hydrochloric acid or sodium hydroxide. Melting racemises the acids. Attempts to convert *trans*- $\alpha\gamma$ -diphenylglutaconic acid into *cis*-acid according to the method of Feist have been found to be unsuccessful.

In order to explain some of the peculiarities of glutaconic acid Thorpe (*J. Chem. Soc.*, 1905, 87, 1869) proposed a normal structure for the stable form. Feist and his co-workers (*Annalen*, 1906, 345, 60) had criticised the theory of normal structure and tried to prove the molecular asymmetry of the acid by optical resolution of a number of glutaconic acids; but all such attempts at resolving the glutaconic acids (open-chain) were unsuccessful, though Feist (*Annalen*, 1924, 436, 135) resolved a cyclic glutaconic acid viz. 3-methylcyclopropene-1 : 2-dicarboxylic acid



However, the normal structure had to be finally discarded as  $\alpha\gamma$ -dimethylglutaconic acid was resolved into optically active forms and hence its asymmetrical structure was proved (McCombs, Packer and Thorpe, *J. Chem. Soc.*, 1931, 547). The  $\alpha\gamma$ -dimethylglutaconic acid was the first open-chain acid to be resolved into optically active forms.

In the present work the asymmetrical character of glutaconic acids has been further proved by the resolution of  $\alpha\gamma$ -diphenylglutaconic acid. This acid (Phalnikar and Nargund, *J. Univ. Bomb.*, 1930, 7, iii, 203) was resolved into optically active forms through its strychnine salt following the method of McCombs *et al.* (*loc. cit.*). The *d*-form could not be obtained in an optically pure form having a rotation equal to that of the *l*-form. A similar observation has been noted in the case of  $\alpha\gamma$ -dimethylglutaconic acid by McCombs *et al.* (*loc. cit.*). The  $\alpha\gamma$ -diphenylglutaconic acid could not be racemised by heating for four hours with hydrochloric acid or sodium hydroxide, but the acid easily racemised on heating above its melting point (235°). It may be noted that  $\alpha\gamma$ -dimethylglutaconic acid readily racemises by boiling with hydrochloric acid or sodium hydroxide (McCombs *et al.*, *loc. cit.*). Another peculiarity of the acid is that it has two distinct melting points. It first melts at 180° and again becomes solid and on further heating melts at 233°.

$\alpha\gamma$ -Diphenylglutaconic acid is most probably a *trans*-acid, although there is no definite evidence in this direction. Attempts are described in the experimental part to convert it into the *cis*-form.  $\alpha\gamma$ -Dimethylglutaconic acid, prepared and resolved by Thorpe is regarded as a *trans*-acid. The *cis*-form of this acid has not been isolated.

## E X P E R I M E N T A L

*Resolution of  $\alpha$ -Diphenylglutaconic Acid*

$\alpha$ -Diphenylglutaconic acid was prepared according to the method of Phalnikar and Nargund (*loc. cit.*).

The method followed for resolving the acid was similar to the one used by McCombs *et al.* (*loc. cit.*) in resolving  $\alpha$ -dimethylglutaconic acid. Strychnine ( $\frac{1}{2}$  equivalent-) was dissolved in chloroform and was added to a cold solution of the acid (4 equivalents) in ether. The precipitated strychnine salt was filtered after half an hour and the precipitate and filtrates were collected separately. The precipitated salt was washed with a mixture of chloroform and ether, and then decomposed by shaking with *N*-ammonia and the solution extracted with chloroform four times to remove all the strychnine. The ammoniacal salt solution of the acid was then decomposed with *N*-hydrochloric acid and the precipitated acid was taken up in ether. The ether layer was washed, dried and ether removed as usual. The residual acid was taken in a beaker and was dried in a vacuum desiccator, weighed and its rotation was found from the 1% solution of the acid in ethyl alcohol. This acid obtained in the first precipitation was fractionally reprecipitated a number of times till the final precipitated acid showed a constant rotation.

A Stanley-Belingham precision type polarimeter with an accuracy of 0.01 degree in sodium light was used. The determinations were carried out in all the cases with a 2 dm. tube at 25°. Absolute alcohol was used for preparing the solutions. Concentration of the solution was 1% (vol.) in each case. Table I summarises the results.

TABLE I

Inactive acid (6 g.)	
Precipitate (I) (2.619 g.)	Filtrate (3.391 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = (50) Combined filtrates (Total weight, 4.381 g.)
Precipitate (II) (1.833 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = - (290)	Filtrate (0.7 g.)
Precipitate (III) (1.263 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = - (310)	Filtrate
Precipitate (IV) (0.8620 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = - (350)	Filtrate (0.3 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = - (254).
Precipitate (V) (0.5008 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = - (350)	Filtrate (0.2 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = - (350)
M.p of the acid, 187—190° and then 233—35°.	

M.p of strychnine salt, 177°—180°;

M.p. of acid, 187—90° and then 233—35°

After the fifth precipitation the specific rotation of the acid from the filtrate and of the acid from the precipitated strychnine salt was identical ( $-350$ ). This shows that the substance was obtained as a pure *laevo*-form.

The filtrate was also subjected to the same treatment in order to obtain the pure *d*-form of the acid, but after the third precipitation it was found that the acid had a rotation which could not be increased by further fractional precipitation. Thus the *d*-form obtained was optically impure. Table II summarises the results.

TABLE II

Combined filtrates (4 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = + (50)	
Filtrate I (1.14 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = + (120)	Precipitate (2.8 g.)
Filtrate II (0.7 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = + (120)	Precipitate (0.35 g.) [ $\alpha$ ] <sub>D</sub> <sup>25</sup> = + (120)
(M. p. of the acid, 187–90° and then 233°).	(M. p. of the acid, 187–90° and then 233°)

As after the second precipitation, the specific rotation of the acid from the precipitate was the same + (120) as that from the filtrate, no further separation was assumed to be possible.

#### Racemisation Experiments

(A) *Boiling with sodium hydroxide.*—*L*-Acid (0.5 g.) was dissolved in 5 c.c. of *N*-sodium hydroxide solution and boiled for 4 hours. The acid was recovered from the sodium salt as usual and its rotation was found. [ $\alpha$ ]<sub>D</sub><sup>25</sup> of the recovered acid =  $-(345)$  and that of the original acid =  $-(350)$ .

This shows that after boiling with sodium hydroxide no racemisation takes place.

(B) *Boiling with hydrochloric acid.*—*L*-Acid (0.25 g.) was boiled for 4 hours with 25 c.c. of *N*-hydrochloric acid. The acid was then filtered, washed with a little water, dried and its rotations measured as [ $\alpha$ ]<sub>D</sub><sup>25</sup> =  $-(350)$ , thus proving that there was no racemisation.

(C) *Synthetic racemic forms.*—*d*-Acid (0.125 g.) and *l*-acid (0.04285 g.) were dissolved in alcohol. The solution was allowed to stand for  $\frac{1}{2}$  hour. The resulting acid was found to be optically inactive.

The *laevo* acid was melted and kept at 235° for 15 minutes. After cooling it was found to be completely inactive. The *dextro*-acid also completely racemised when treated in the same way.

#### Attempts to convert *trans*- $\alpha\gamma$ -Diphenylglutaconic Acid to *cis*-Acid

The anhydride of the acid (m. p. 118–119°) was hydrolysed by the method followed by Feist (*Annalen*, 1909, 370, 41) for conversion of  $\alpha\gamma$ -dimethylglutaconic acid from *trans* to *cis*.

Equivalent quantities of the anhydride and casein were mixed and heated with  $N/10$  sodium hydroxide solution. It was then kept at room temperature for 3 days till the solution became slightly acidic. It was precipitated with silver nitrate. The silver salt was filtered, suspended in dry ether and through it dry  $H_2S$  was passed. The precipitate of silver sulphide was filtered off, and the acid, after removing the ether, was crystallised. Its melting point was found to be  $175-80^\circ$  and then  $230-33^\circ$  thus proving that no conversion was effected.

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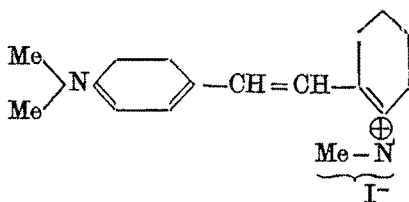
Received September 6, 1946

## THE CYANINE DYES OF THE PYRIDINE SERIES. PART V.

BY M. Q. DOJA AND KAILASH BIHARI PRASAD

*p*-Dimethylamino- and *p*-diethylamino-benzaldehydes have been condensed with  $\alpha$ -,  $\beta$ - and  $\gamma$ -picoline-methiodide and the chemical, dyeing and photographic properties of the compounds, thus produced, examined. The influence of the change in position of the attachment of the dialkylamino-benzaldehyde residue to the pyridine ring has also been discussed.

In the valuable photographic sensitiser (S), first prepared by Pope and Mills (*J. Chem. Soc.*, 1922, 121, 946), the effect of change of the alkyl radical attached to



(S)

the tertiary and the quaternary nitrogen atoms, and the acid radical, on the sensitising characteristics of the compound has been reported in previous papers of this series (Doja, *J. Indian Chem. Soc.*, 1940, 17, 347; Doja *et al.*, *ibid.*, 1942, 19, 125, 377; 1946, 23, 117). In the present work, the influence of the change in the position of attachment of the *p*-dialkylaminobenzaldehyde residue to the pyridine ring has been investigated.  $\alpha$ -,  $\beta$ - and  $\gamma$ -Picoline-methiodides have been condensed with *p*-dimethylamino- and *p*-diethylamino-benzaldehydes and the resulting dyestuffs examined. For a good yield it is essential that the constituents should be completely dry, and the condensation carried out in the absence of moisture. Two sets of compounds, (A, B, C) and ( $A_1$ ,  $B_1$ ,  $C_1$ ) have been prepared. The first set has been obtained by the condensation of *p*-dimethylaminobenzaldehyde with  $\alpha$ -picoline-methiodide (A),  $\beta$ -picoline-methiodide (B) and  $\gamma$ -picoline-methiodide (C) respectively, and the second set by the condensation of *p*-diethylaminobenzaldehyde with  $\alpha$ -picoline-methiodide ( $A_1$ ),  $\beta$ -picoline-methiodide ( $B_1$ ) and  $\gamma$ -picoline-methiodide ( $C_1$ ). Some of the properties of these compounds are recorded in Table I.

Although A (Pope and Mills, *loc. cit.*) and  $A_1$  (Doja and Prasad, *J. Indian Chem. Soc.*, 1942, 19, 125) have been described before, they have been prepared again under conditions similar to the other compounds and their properties included for the sake of comparison.

In each set, it will be seen, the *ortho* compound (A and  $A_1$ ) has the highest and the *meta*-compound (B and  $B_1$ ), the lowest melting points.

It is noteworthy that the yields of these compounds are very high, whereas cyanine dyes usually give poor yields.

TABLE I

Compound.	Colour & shape of crystals.	M.p.	Yield.	Reflex.	Pleochroism.		Relative resistance to decolorisation.		Relative intensity of colour in solution.	Extra sensitisation		Remarks.
					position One.	⊥ position.	Aq. soln.	Alcoholic soln.		Ranges. in Å	Maximum. in Å	
A	Vermilion red, needles	265°	82.9%	Blue	Yellowish red	Nearly opaque	7.2	22.1	1	4900—6100	5500	Ortho
B	Dark chocolate, microscopic crystals	247°	81.8	Very weak blue	Amethyst (very weak)	Dark red	7.9	18.2	14.55	4800—6300	5600	Meta
C	Vermilion, tiny felted needles	261.5°	76.1	Weak blue	Orange	Blood red	6.6	18.6	1.01	4800—5900	5400	Para
A <sub>1</sub>	Light mauve, flattened needles	240°	78.1	Strong scintillating light blue	Deep pink	Nearly opaque	1	8.2	2.01	4850—6000	5450	Ortho
B <sub>1</sub>	Light chocolate, stunted needles	222°	83.5	Green	Bright cherry red	Nearly opaque	1.4	9.1	28.87	4800—6350	5600	Meta
C <sub>1</sub>	Mauve, stout needles	232.5	86.3	Strong scintillating blue	Orange-red	Bluish red	1.2	7.1	1.79	4800—5900	5400	Para

In conformity with the observations of Mills and Pope (*Phot. J.*, 1920, **44**, 255), it has been found that these dyes are decolorised by the addition of mineral acid both in aqueous and alcoholic solutions; the latter being more resistant than the former. The "Relative resistance to decolorisation", shown in Table I, has been determined by finding the value of  $N/100\text{-HCl}$  required to decolorise 2 c.c. of 1/100,000 solution of the dyes, and dividing the figures, thus obtained, by the smallest among these. It will be noticed that the compounds of the first set in the dimethylamino dyes are more resistant to decolorisation than those of the second set in the diethylamino dyes. The colour produced on silk, wool and cotton, when dyed with these compounds, is given in Table II. There is little difference in shade by the use of a neutral or an acid bath. The best shade is produced on wool, and this has the maximum resistance to fading too, comparatively speaking. Like other cyanine dyes, colour of these compounds also is neither fast to sunlight nor to washing. All these compounds produce beautiful crystals, which are freely soluble in methyl alcohol, ethyl alcohol and water, forming light orange coloured solutions in the case of A, C and A<sub>1</sub>, C<sub>1</sub> and cherry-red solutions in the case of B and B<sub>1</sub>. The alcoholic solution in each case, is clearer and more deeply coloured than the corresponding aqueous solution. The *meta* dyes, B and B<sub>1</sub>, are less soluble in these solvents than the *ortho* and *para* dyes, A, A<sub>1</sub> and C, C<sub>1</sub>. The

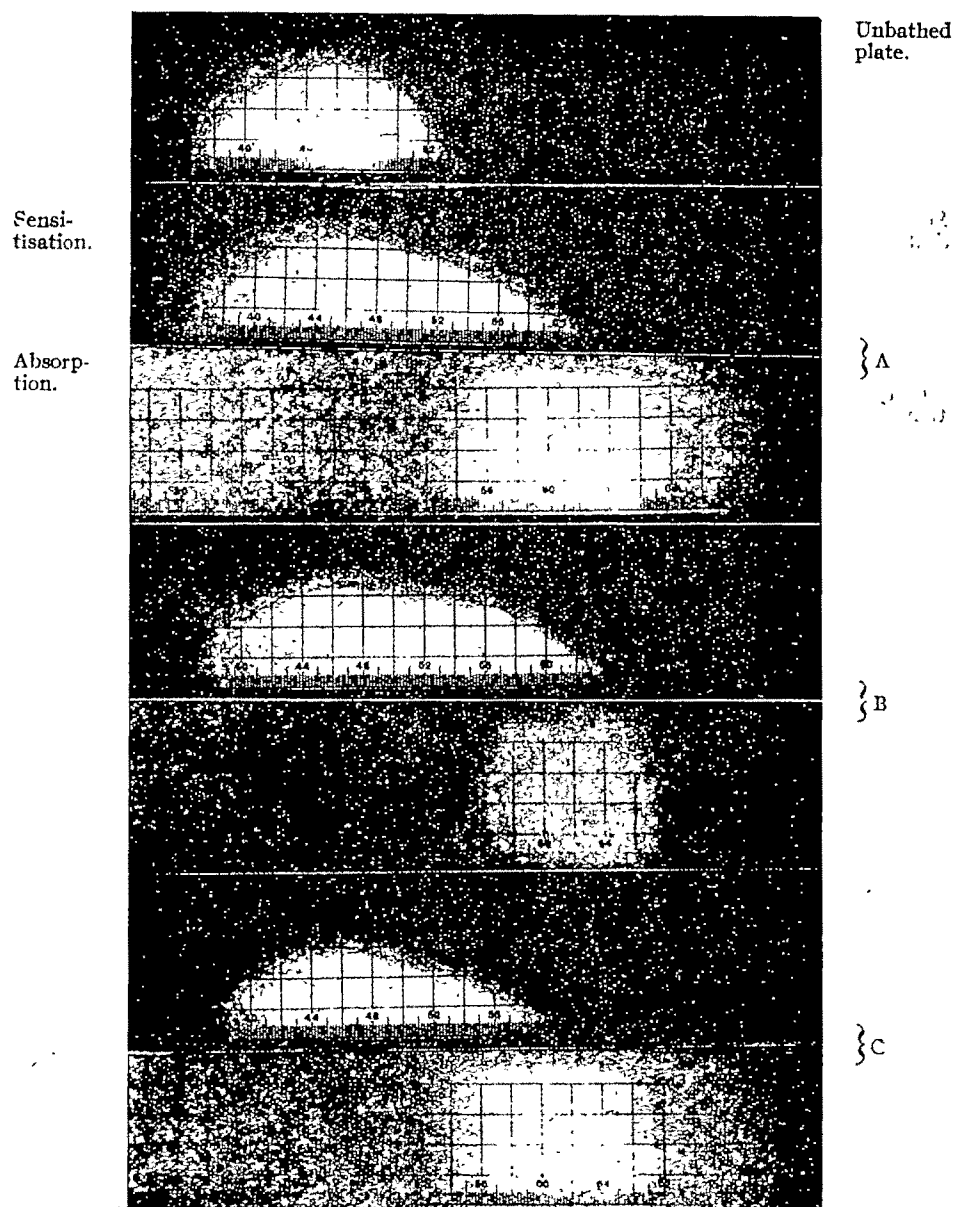


FIG. 1.

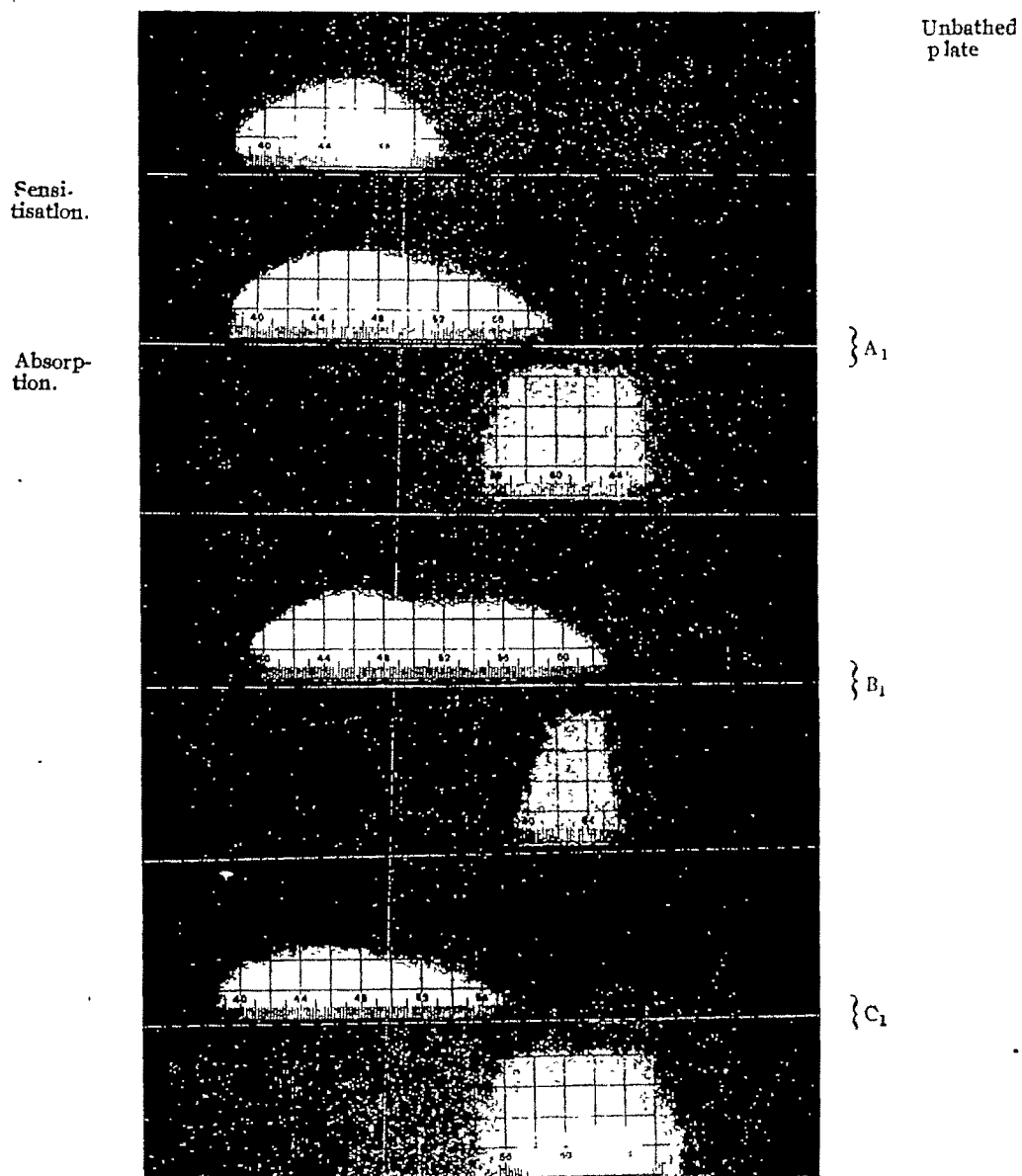


FIG. 2.



compounds are all insoluble in ether, benzene and chloroform. The "Relative intensity of colour" in alcoholic solutions (1:1000), determined in the usual way by means of a Duboseq colorimeter, is given in Table I. The higher intensity of the two *meta* compounds (B, B<sub>1</sub>) and the large difference between them are noteworthy.

The fluorescence of weak alcoholic solution (1:100,000) of these dyes is given in Table III (*cf.* Doja, *loc. cit.*).

In Figures 1, 2 are shown the absorption and sensitisation spectra of these compounds and in Table I are given the ranges and maxima of the extra sensitisation bands.

It will be noticed that both the *meta* compounds, B and B<sub>1</sub>, are powerful "Green" sensitisers; in the quality, they surpass even the compound prepared by Mills and Pope (*loc. cit.*). The extra sensitisation bands are intense, uniform and "blue-green-gap"-free. As is to be expected, the heavier compound B<sub>1</sub>, has a slightly longer band of extra sensitisation.

TABLE II

Compound.	Colour produced on		
	Silk.	Wool.	Cotton.
A	Saffron	Orange-yellow	Turmeric-yellow
B	Beetroot red	Dirty magenta	Magenta
C	Bright orange-yellow	Deep orange-yellow	Dull brownish yellow
A <sub>1</sub>	Bright orange-yellow	Deep orange-yellow	Dull brownish yellow
B <sub>1</sub>	Bluish red	Deep bluish red	Weak bluish red
C <sub>1</sub>	Orange-yellow	Deep orange-yellow	Dull yellow

So far as this series goes, our investigations show, that among the *ortho*-, *para*- and *meta*- dyes of the same type, the *meta* compound is the most powerful sensitiser. Why is this so is a question, which has yet to be answered. In view of the well known similarity between the *ortho* and the *para* positions, the resemblance in properties recorded in this paper, between A, C and A<sub>1</sub>, C<sub>1</sub> on the one hand, and B and B<sub>1</sub> on the other, is interesting.

## EXPERIMENTAL

The absolute alcohol used in these experiments, was in each case, freshly redistilled over quicklime and tested water-free, before being used. The picolines were all purified through their picrates, before quaternisation.

2-*p*-Dimethylaminostyryl-pyridine-methyl iodide (A) was prepared according to the method of Mills and Pope (*loc. cit.*) (Found: I, 34.34. C<sub>18</sub>H<sub>19</sub>N<sub>2</sub>I requires I, 34.69 per cent).

3-*p*-Dimethylaminostyryl-pyridine-methyl iodide (B) was prepared by heating together β-picoline-methiodide (0.4 g.), *p*-dimethylaminobenzaldehyde (0.4 g.), piperidine (5 drops) and absolute alcohol (8.5 c.c.), to a brisk boil for five hours. The reaction mixture turned yellow, then orange and finally deep orange; and on cooling, the separated crystals were filtered washed with alcohol-ether and recrystallised from methyl alcohol, yield 0.509 g. (Found: I, 34.48. C<sub>18</sub>H<sub>19</sub>N<sub>2</sub>I requires I, 34.69 per cent).

4-*p*-Dimethylaminostyryl-pyridine-methyl iodide (C).—*p*-Dimethylaminobenzaldehyde (0.29 g.),  $\gamma$ -picoline-methiodide (0.41 g.) and piperidine (6 drops) were dissolved in absolute alcohol (9 c.c.) and the solution refluxed for 6 hours. The solution on cooling deposited crystals, which were recrystallised from absolute methyl alcohol, yield, 0.480 g. (Found : I, 34.51.  $C_{16}H_{18}N_2I$  requires I, 34.69 per cent).

2-*p*-Diethylaminostyryl-pyridine-methiodide ( $A_1$ ) was obtained by the method of Doja and Prasad (*loc. cit.*). (Found : I, 32.19.  $C_{18}H_{23}N_2I$  requires I, 32.23 per cent).

3-*p*-Diethylaminostyryl-pyridine-methiodide ( $B_1$ ) was prepared by heating a solution of *p*-diethylaminobenzaldehyde (0.35 g.),  $\beta$ -picoline methiodide (0.40 g.) and piperidine (5 drops) in absolute alcohol (8.5 c.c.) on a water-bath for 5 hours. The deep red solution, thus obtained, was cooled, and the separated crystals, recrystallised from methyl alcohol, yield 0.56 g. (Found : I, 32.15.  $C_{18}H_{23}N_2I$  requires I, 32.23 per cent).

TABLE III

Wallace colour filter No.	Colour of the fluorescent beam seen at right angles to the incident beam					
	A	B	C	$A_1$	$B_1$	$C_1$
1	Weak red	Light absorbed	Cherry red	Weak red	Crimson red	Light absorbed
2	Weak red	Rose red	Weak red	Crimson red	Pink	Rose red
3	Greenish yellow	Claret red	Dull yellow	Pink	Weak red	Grass green
4	Faint pink	Pink	Light absorbed	Reddish yellow	Rose red	Weak rose red
5	Dull yellow	Yellowish pink	Yellow	Weak yellow	Cherry red	Yellow
6	Dull yellow	Rose red	Weak yellow	Do	Very weak red	Yellow
7	Dull yellow with an orange tinge	Dull yellow	Lemon yellow	Grass green	Claret red	Dull yellow
8	Do	Yellowish red	Reddish yellow	Weak green	Orange	Yellowish orange
9	Yellow	Absorbed	Grass green	Weak bluish green	Light absorbed	Lemon yellow
10	Yellow	Orange	Bottle green	Weak orange	Weak red	Greenish

4-*p*-Diethylaminostyryl-pyridine-methyl iodide ( $C_1$ ) was obtained by refluxing together *p*-diethylaminobenzaldehyde (0.35 g.),  $\gamma$ -picoline-methiodide (0.47 g.) and piperidine (1 c.c.) dissolved in absolute alcohol (8.5 c.c.) for 5 hours. Within a few minutes the solution became red and crystals began to separate. These were filtered out, after cooling, and recrystallised from methyl alcohol, yield 0.68 g. (Found : I, 32.19,  $C_{18}H_{23}N_2I$  requires 32.23 per cent).

# VARIATION OF APPARENT MOLAR VOLUME OF NON-ELECTROLYTES IN SOLUTION WITH CONCENTRATION. PART II.

BY S. O. SHUKLA AND W. V. BHAGWAT

The apparent molar volume of non-electrolytes does not seem to vary very much with concentration. This is true of binary and ternary mixtures. The systems urea, glucose, and water ; glucose acetamide and water ; ethyl acetate, toluene and benzene, and ethyl acetate, benzene and carbon tetrachloride have been studied.

In a previous paper (*J. Indian Chem. Soc.*, 1945, 22, 186) we have shown that apparent molar volume of a non-electrolyte in solution does not seem to vary very much with variation in concentration. The work is extended in this paper. For binary mixture the expression used is

$$\frac{M}{D} \cdot \frac{m_1}{d_1} = 1 + mx - x$$

where  $M$ ,  $D$ ,  $m_1$ ,  $d_1$  and  $x$  have the same significance as given in the previous paper (*loc. cit.*).

TABLE I

$x$ .	$M/D$ .	$\frac{M/D}{m_1/d_1}$ .	$m$ .	$x$ .	$M/D$ .	$\frac{M/D}{m_1/d_1}$ .	$m$
(1) $\text{OBr}_4$ in $\text{CCl}_4$ ( $m_1/d_1=97.01$ ).				(2) Tetranitromethane in benzene ( $m_1/d_1=69.84$ ).			
0.1436	97.83	1.0084	1.058	0.3377	100.9	1.1231	1.364
0.2097	103.9	1.0710	1.038	0.5082	106.6	1.1798	1.354
0.2945	99.17	1.0223	1.075	0.6736	111.1	1.2366	1.351
0.3746	99.88	1.0296	1.079	0.8561	116.2	1.2934	1.343
0.4211	100.2	1.0328	1.077				
(3) Glucose in water ( $m_1/d_1=18.05$ ).				(4) Urea in formamide ( $m_1/d_1=38.83$ ).			
0.006582	18.69	1.0354	6.38	0.02622	39.06	1.0059	1.158
0.007741	18.78	1.0404	6.22	0.03824	39.08	1.0064	1.158
0.01196	19.15	1.0609	6.09	0.04735	39.12	1.0077	1.162
				0.05853	39.17	1.0087	1.149
(5) Fructose in pyridine ( $m_1/d_1=81.16$ ).				(6) Urea in methyl alcohol ( $m_1/d_1=40.59$ ).			
0.02507	82.04	1.0103	1.43	0.05480	40.34	0.9938	0.862
0.03217	82.24	1.0133	1.42	0.06756	40.27	0.9928	0.868
0.06503	88.08	1.0236	1.38	0.08000	40.26	0.9921	0.883
				0.08194	40.19	0.9918	0.897
				0.1028	40.05	0.9901	0.878
						0.9866	0.869
(7) Urea in EtOH ( $m_1/d_1=58.76$ )				(8) Thiourea in pyridine ( $m_1/d_1=81.12$ ).			
0.01037	58.55	0.9964	0.652	0.04214	79.64	98.17	0.565
0.01547	58.41	0.9940	0.612	0.06132	78.98	97.36	0.569
0.02054	58.33	0.9927	0.644	0.07741	78.39	96.63	0.564
0.03232	58.09	0.9884	0.641	0.08561	78.23	95.43	0.583
0.01007	57.94	0.9860	0.650	0.09493	77.78	95.88	0.566
				0.1019	77.64	95.71	0.578

Results of sections (1) and (2) have been calculated on the basis of parachor values of Hammick and Wilmut (*J. Chem. Soc.*, 1934, 32) and from Ray's work (*J. Indian Chem. Soc.*, 1934, 11, 843 ; 1935, 12, 404).

*Ternary System.*

For ternary mixture containing  $x$  and  $y$  molar fractions of solutes whose molecular weights are  $m_2$  and  $m_3$ , we have shown in the previous paper (*loc. cit.*) that

$$M/D = (1-x-y)v_1 + xv_2 + yv_3$$

where  $v_1$ ,  $v_2$ , and  $v_3$  are the molar volumes in solution for the solvent and solutes; and  $M$  and  $D$  are the mean molecular weight and the density of the solutions.

In calculating the molar volumes of glucose, acetamide and urea, the densities employed are those observed by us in solution and given in the previous paper (*loc. cit.*). For liquids, the densities of pure liquids at the corresponding temperatures have been substituted.

TABLE II

*Molecular volume.*

Substance.	$m/d$ .	Substance.	$m/d$ .
Benzene	78/0.8661 = 90.071	Glucose	= 100.28
Toluene	92/0.8558 = 107.501	Urea	60/1.345 = 44.61
Ethyl acetate	88/0.8907 = 98.795	Acetamide	59/1.065 = 55.39
Carbon tetrachloride	154/1.578 = 97.592		

For glucose the molecular volume  $v_2$  is found from the expression  $v_2/v_1 = m$ . The value of  $m$  is 5.553 and  $v_1$  for water is at the same temperature  $18/0.997 = 18.05$ . Hence  $v_2 = 18.05 \times 5.553 = 100.28$ .

TABLE III

*Ethyl acetate-toluene-benzene system.*

$M/D$ .	$(1-x-y)v_1 + xv_2 + yv_3$ .
(1) $\frac{86.06}{0.8693} = 98.99$	$0.3393 \times 90.07 + 0.3114 \times 98.789 + 0.3493 \times 107.501 = 98.80$
(2) $\frac{86.22}{0.8735} = 98.72$	$0.2764 \times 90.07 + 0.4868 \times 98.8 + 0.2368 \times 107.5 = 98.44$
(3) $\frac{86.71}{0.8676} = 99.95$	$0.3008 \times 90.07 + 0.2874 \times 98.8 + 0.4118 \times 107.5 = 99.73$
(4) $\frac{86.88}{0.8714} = 99.70$	$0.2623 \times 90.07 + 0.3636 \times 98.8 + 0.3741 \times 107.5 = 99.75$
(5) $\frac{85.55}{0.8672} = 98.68$	$0.3961 \times 90.07 + 0.2346 \times 98.8 + 0.3693 \times 107.5 = 98.54$

*Ethyl acetate-benzene-carbon tetrachloride system.*

$M/D$ .	$(1-x-y)v_1 + xv_2 + yv_3$ .
(1) $\frac{106.9}{1.117} = 95.74$	$0.3448 \times 90.07 + 0.3115 \times 97.59 + 0.3437 \times 98.8 = 95.63$
(2) $\frac{110.8}{1.156} = 95.15$	$0.3114 \times 90.07 + 0.3924 \times 97.59 + 0.2962 \times 98.8 = 95.80$
(3) $\frac{100.1}{1.058} = 94.61$	$0.4649 \times 90.07 + 0.2539 \times 97.59 + 0.2812 \times 98.8 = 94.70$

$$(4) \frac{102.4}{1.078} = 94.97 \quad 0.2807 \times 90.07 + 0.2776 \times 97.59 + 0.4417 \times 98.8 = 96.19$$

$$(5) \frac{119.3}{1.235} = 96.61 \quad 0.2646 \times 90.07 + 0.5060 \times 97.59 + 0.2294 \times 98.8 = 96.06$$

Glucose-acetamide-water system.

$M/D.$

$(1-x-y) v_1 + xv_2 + yv_3$

$$(1) \frac{31.2}{1.087} = 28.7 \quad 0.023 \times 100.28 + 0.2233 \times 55.39 + 0.7537 \times 18.05 = 28.44$$

$$(2) \frac{29.76}{1.092} = 27.26 \quad 0.0288 \times 100.28 + 0.1735 \times 55.39 + 0.7980 \times 18.05 = 26.875$$

$$(3) \frac{29.30}{1.087} = 26.96 \quad 0.02616 \times 100.28 + 0.1719 \times 55.39 + 0.8019 \times 18.05 = 26.612$$

$$(4) \frac{28.24}{1.071} = 26.36 \quad 0.1701 \times 100.28 + 0.0189 \times 55.39 + 0.8110 \times 18.05 = 26.815$$

$$(5) \frac{30.97}{1.069} = 28.97 \quad 0.2395 \times 100.28 + 0.0177 \times 55.39 + 0.7428 \times 18.05 = 28.72$$

Urea-glucose-water system.

$M/D.$

$(1-x-y) v_1 + xv_2 + yv_3$

$$(1) \frac{26.68}{1.140} = 23.05 \quad 0.9628 \times 44.61 + 0.02853 \times 100.28 + 0.8752 \times 18.05 = 22.956$$

$$(2) \frac{27.61}{1.207} = 24.52 \quad 0.1207 \times 44.61 + 0.02805 \times 100.28 + 0.8513 \times 18.05 = 23.566$$

$$(3) \frac{28.63}{1.159} = 24.73 \quad 0.1392 \times 44.61 + 0.0297 \times 100.28 + 0.8311 \times 18.05 = 24.198$$

$$(4) \frac{25.93}{1.133} = 22.89 \quad 0.07660 \times 44.61 + 0.02918 \times 100.28 + 0.8942 \times 18.05 = 22.256$$

$$(5) \frac{26.44}{1.132} = 23.35 \quad 0.1224 \times 44.61 + 0.0203 \times 100.28 + 0.8573 \times 18.05 = 23.571$$

$$(6) \frac{27.39}{1.144} = 23.94 \quad 0.1463 \times 44.61 + 0.0200 \times 100.28 + 0.8337 \times 18.05 = 23.577$$

$$(7) \frac{24.79}{1.116} = 23.22 \quad 0.0778 \times 44.61 + 0.0216 \times 100.28 + 0.9006 \times 18.05 = 21.896$$

$$(8) \frac{25.47}{1.122} = 22.70 \quad 0.0963 \times 44.61 + 0.0211 \times 100.28 + 0.8826 \times 18.05 = 22.845$$

## QUINOLINE DERIVATIVES. PART XIV.

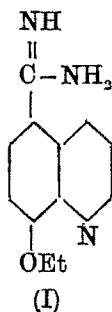
By T. N. GHOSH

In search for a potent and dependable amoebicidal drug, 8-ethoxyquinoline-5-amidine has been synthesised.

According to Payne (*Lancet*, 1945, *i*, 206) and other clinicians, the incidence of amoebiasis is surprisingly high, the diagnosis often difficult and elusive, the treatment unsatisfactory and the relapse rate disappointing. Derivatives of 8-hydroxyquinoline, such as Vioform, Chiniofon and Diodoquin, have been found to possess pronounced amoebicidal properties but none provides a guaranteed cure and there is therefore abundant need to discover more potent and dependable amoebicidal drugs.

In recent years much attention has been devoted to the parasiticidal properties of various amidine derivatives. The recent observations on the trypanocidal properties of various aromatic diamidines (King, Lourie and Yorke, *Lancet*, 1937, *233*, 136; Ashley, Barber, Ewins, Newbery and Self, *J. Chem. Soc.*, 1942, 103; Kirk and Sati, *Ann. Trop. Med. Parasitol.*, 1940, *34*, 82; Adams and Yorke, *ibid.*, 1939, *33*, 323; 1940, *34*, 174) have opened up a new line of research along which important therapeutic substances may be discovered. Paludrine, which is an amidine derivative of a type not hitherto met with in chemotherapy, has been found to possess pronounced antimalarial properties (Rose, Curd and Davey, *Brit. Med. J.*, 1945, *2*, 653). In view of these observations on the activity of amidine derivatives against parasitic diseases, it has been considered desirable to prepare a derivative of 8-hydroxyquinoline containing an amidino group. Such a compound is expected to possess pronounced amoebicidal properties.

Attempts to prepare 5-cyano-8-hydroxyquinoline by heating the potassium salt of 8-hydroxyquinoline-5-sulphonic acid with potassium cyanide at 250°, or to obtain directly the corresponding amidine derivative by heating the ammonium salt of 8-hydroxyquinoline-5-sulphonic acid with a cyanide at 200-250° (*cf.* Oxley and Short, *J. Chem. Soc.*, 1946, 147) were not successful, 8-hydroxyquinoline being formed in each case. However, 5-amino-8-ethoxyquinoline (Vis, *J. prakt. Chem.*, 1892, *ii*, *48*, 531) has now been converted into 5-cyano-8-ethoxyquinoline. This cyano compound has yielded 8-ethoxyquinoline-5-amidine (I), *via* the corresponding imino-ether hydrochloride.



## E X P E R I M E N T A L

*5-Nitro-8-ethoxyquinoline.*—Vis (*loc. cit.*) obtained a mixture of 5-nitro-8-ethoxyquinoline and the corresponding dinitro derivative by nitrating 8-ethoxyquinoline (1 vol.) with fuming nitric acid (4 vols.). Under the following conditions only the 5-nitro-derivative has now been obtained in almost quantitative yield.

To 50 c. c. of fuming nitric acid (*d* 1.52) was added dropwise 8-ethoxyquinoline (25 c. c.) and the solution was allowed to remain at room temperature for 1 hour, then heated on the water-bath at 70-75° for 3 hours, cooled and finally poured into a large quantity of water. The resulting solution was then basified with sodium carbonate when a light yellow precipitate was obtained. It was filtered next day, washed thoroughly with water and was crystallised from alcohol (95%) in light yellow needles, m. p. 127-28°.

*5-Amino-8-ethoxyquinoline.*—The following method of reduction of 5-nitro-8-ethoxyquinoline has been found to be quite suitable.

To a solution of 5-nitro-8-ethoxyquinoline (30 g.) in alcohol (95%, 215 c. c.) water (55 c. c.) was added and the solution was mixed with iron powder (60 g.). The mixture was then heated on the water-bath under reflux in a three-necked flask fitted with a stirring arrangement, and hydrochloric acid (3.5 c. c. in 25 c. c. water) was added dropwise during 2 hours. After addition was over, the mixture was further heated for 2 hours, basified with sodium carbonate and filtered while hot. The filtrate was distilled under reduced pressure and the residue was washed thoroughly with cold water and was crystallised from hot water (charcoal) in yellow plates (16 g.), m. p. (when anhydrous) 114° (*cf.* Vis, *loc. cit.*).

*Attempt to prepare 5-Cyano-8-hydroxyquinoline.*—An intimate mixture of the potassium salt of 8-hydroxyquinoline-5-sulphonic acid (12 g.) and potassium cyanide (5 g.) was heated in a paraffin bath at 250° for 4 hours. On cooling, the fused mass was triturated with water and filtered. The residue was dissolved in dilute hydrochloric acid and the solution, after being shaken with charcoal, was filtered. The filtrate, when basified with sodium carbonate, gave a precipitate which was crystallised from dilute alcohol in cream-coloured needles, m. p. 74-75°, and was proved to be 8-hydroxyquinoline.

*5-Cyano-8-ethoxyquinoline.*—5-Amino-8-ethoxyquinoline hydrochloride (35 g.) was dissolved in a mixture of concentrated hydrochloric acid (60 c. c.) and water (140 c. c.), and the resulting solution was diazotised at 0° with 1% sodium nitrite solution (100 c. c.). After 1 hour the solution was added with vigorous stirring to excess of cuprous cyanide solution and the mixture was then heated on the water-bath at 60° for 1 hour and left overnight. Next day the brown solid was filtered, washed thoroughly with water, dried in a hot place and extracted with boiling alcohol twice. The alcoholic solution on distillation gave a solid which was twice crystallised from alcohol (charcoal) in colourless slender needles m. p. 129-30°, yield 14 g. (Found: N, 14.08.  $C_{12}H_{10}ON_2$  requires N, 14.14 per cent).

The *picrate* crystallised from hot alcohol in fine yellow needles, m. p. 172-73°.

*8-Ethoxyquinoline-5-amidine* (I).—Dry hydrogen chloride was passed into a solution of 5-cyano-8-ethoxyquinoline (3 g.) in absolute alcohol (8 c. c.) and dry ether (35 c. c.)

cooled in ice, and the solution was kept in a closed vessel in the refrigerator for 4 days. A small quantity of a light brown precipitate was obtained, which was filtered and was found to be 5-cyano-8-ethoxyquinoline hydrochloride. The filtrate, when kept in the closed vessel in the refrigerator for about 10 days more, deposited a light yellow precipitate (8-ethoxyquinoline-5-imino-ether hydrochloride), which was filtered, washed with dry ether and added to 15% alcoholic ammonia (50 c. c.) and occasionally shaken at room temperature for 4 days. The precipitate (ammonium chloride) was filtered and the filtrate concentrated under reduced pressure, when a solid (the corresponding amidine hydrochloride) was obtained. This amidine hydrochloride was then treated with excess of aqueous ammonia and the residual white solid was filtered, washed with water and was crystallised from dilute alcohol in colourless rectangular plates m. p. 260-62°, yield 0.8 g. (Found in a sample dried at 120-125° in *vacuo* : N, 19.27.  $C_{12}H_{13}ON_3$  requires N, 19.53 per cent).

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## METHOD OF DETERMINING THE AVERAGE PARTICLE SIZE IN GUNCOTTON PULP

BY G. FOGES AND G. KRISHNASWAMY

A method for determining the fineness of the guncotton pulp is described. The method is based on the principle of determining the relative specific surface area, by the rate of liquid flow through an assemblage of guncotton particles in a standard state of packing. The theory on which the method is based is discussed and it is shown how the relative figures obtained are dependent on the specific surface area and how they can be correlated with microscopic measurements of the average particle size.

The apparatus used for the experiments and the procedure of testing are described including the method developed for obtaining an assemblage of guncotton particles in a standard state of packing.

The results of actual plant tests are shown and a simplified apparatus for routine tests suggested.

An increasing number of industrial processes depend on an adequate control of particle size and various methods have been developed for controlling the particle size of powdered materials.

On the other hand, corresponding methods for pulp have not been developed to the same extent, and therefore the process of pulping still largely depends on "rule of thumb".

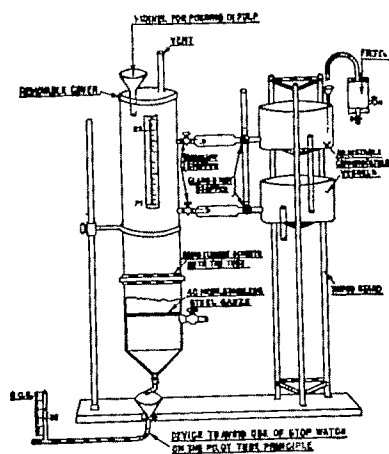
Attempts have been made to judge the fineness of pulp with an apparatus designed by Schopper and Riegler, wherein the "freeness" with which water parts from paper pulp is determined; but as far as it is known here, nothing has been published regarding the scientific basis of this test.

Preliminary experiments carried out here have indicated that sedimentation methods as developed for powdered materials cannot be considered reliable when applied to pulp. The considerable amount of air enclosed in the pores causes conditions in which Stoke's law is inapplicable and bigger particles can be observed settling more slowly than smaller ones.

The only method which hitherto allows an estimate of the relative size and distribution of particles in guncotton pulp is the microscopic method. This method is slow and to a large extent dependent upon the human factor, but it does permit direct measurement.

Fig. 1 shows the broken up fibres of guncotton pulp after beating as they appear under the microscope. This shows a collection of agglomerated fibres and single fibres most of them being twisted. There is thus no possibility of determining an absolute particle size in guncotton pulp and all that can be done is to make relative measurements. According to the same fixed arbitrary procedure, we have, for example, measured the length of the circumscribed rectangle around each particle and Fig. 2 shows the distribution curves on this basis for pulp after different times of beating.

The microscopic method is, however, far too slow to be used regularly for controlling the process of beating. Sedimentation methods apart from being slow as well, are not at all reliable for pulp for reasons mentioned above and the "freeness" test is entirely empirical and arbitrary.



NOTE COMMUNICATING VESSEL CAN BE OPENED TO THE THER  
ONLY WHEN THE POSSIBILITY OF THE PUMP FLOWING BACK  
INTO THE COMMUNICATING VESSEL IS ASSURED.

FIG. 4.



FIG. 1

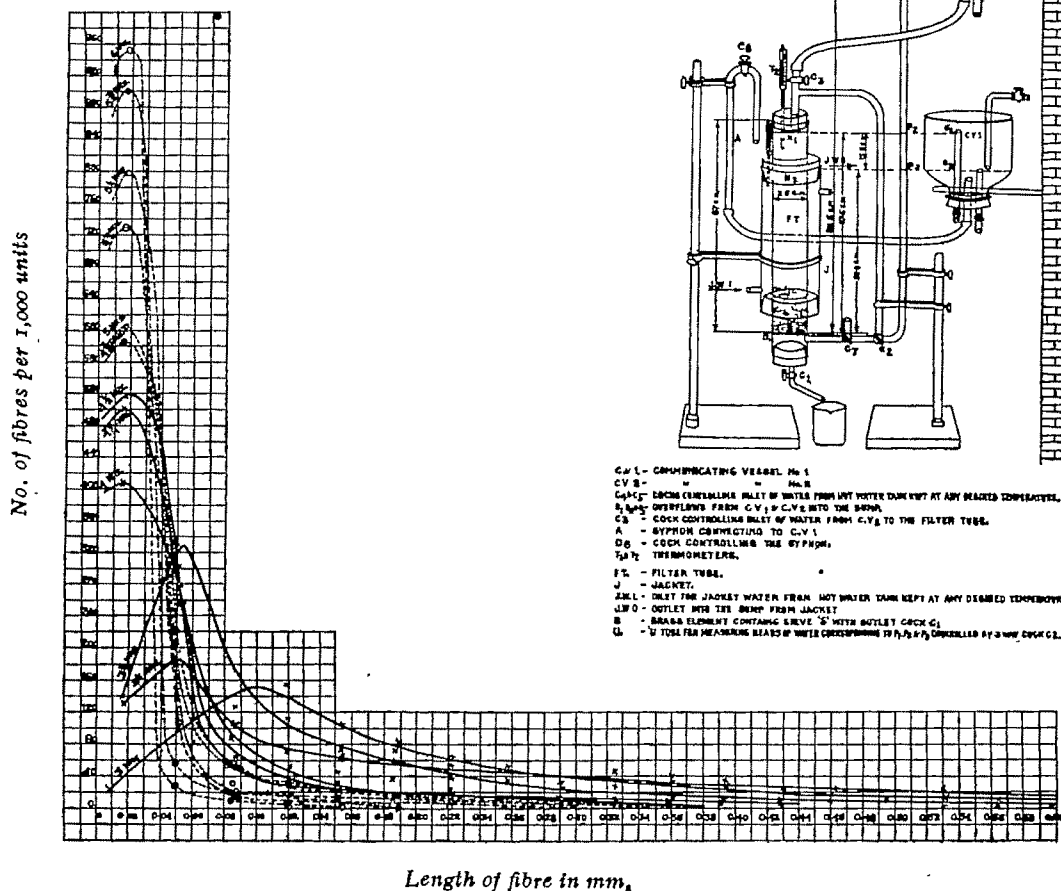


FIG. 2.

The problem has therefore been approached from a different angle and a test based on first principles has been developed here wherein results can be correlated to the microscopic measurements. Our method is based on the determination of the relative specific surface area, as measured by the rate of liquid flow through an assemblage of guncotton particles in a standard state of packing.

The rate of liquid flow through the fine pores of a cake, formed by fibres after settling, is under certain conditions subject to Poisseuille's law for viscous flow. Whether or not these conditions prevail in our experiment cannot be said off hand, since neither average pore diameter nor the length of the pores is known and Reynold's number cannot be determined directly.

There is, however, an indirect method for judging whether viscous (laminary) or turbulent flow prevails, which is based on the following consideration:—

Assuming that the conditions of laminary flow prevail, then if a liquid moves through a tube of circular cross-section, Poisseuille's equation applies.

$$P = \frac{32L\mu W}{gD^2} \quad \dots (1)$$

$P$  = drop in pressure in lbs/sq. in,  $L$  = length of the tube in feet,  $W$  = velocity in feet/sec.,  $\mu$  = viscosity of liquid in lbs/foot/second,  $D$  = diameter of the tube in feet and  $g$  = acceleration due to gravity in feet/second.

$$W = \frac{PgD^2}{32L\mu}$$

Let " $v$ " be the volume of filtrate per capillary collected per second at a pressure drop  $\Delta P$ , then

$v$  = cross-section area of the capillary  $\times$  velocity.

$$v = \frac{\pi D^2}{4} W = \frac{\Delta P \cdot g \cdot \pi D^2 \cdot D^2}{32 \cdot L \cdot \mu \cdot 4} = \frac{\pi D^4 \cdot \Delta P g}{128 \mu L}$$

Considering the average properties of the cake and assuming that there are ' $n$ ' capillaries of equal diameter and length corresponding to the average dimensions of ' $n$ ' pores,

Then the volume " $V$ " of liquid collected per second

$$V = nv = \frac{n\pi D^4 g}{128 \mu L} \times \Delta P \quad \dots (2)$$

For any particular cake  $n$ ,  $D$  and  $L$  are constant.

For any particular liquid  $\mu$  is constant at constant temperature.

$$V = \frac{n\pi D^4 g}{128 \mu L} \times \Delta P. \quad \text{Let} \quad \frac{n\pi D^4 g}{128 \mu L} = k_1 \text{ (a constant). Then } V = k_1 \cdot \Delta P.$$

By varying the pressure difference ( $\Delta P$ ) we may obtain the following set of equations for different rates of flow ( $V$ ).

$$\begin{aligned} V_1 &= k_1 \cdot \Delta P_1; \quad V_1 - V_2 = k_1 (\Delta P_1 - \Delta P_2) & V_2 &= k_1 \Delta P_2; \quad V_2 - V_3 = k_1 (\Delta P_2 - \Delta P_3) \\ V_3 &= k_1 \cdot \Delta P_3; \end{aligned}$$

$$\frac{V_1 - V_2}{V_2 - V_3} = \frac{\Delta P_1 - \Delta P_2}{\Delta P_2 - \Delta P_3} \quad \dots (3)$$

(Assuming that  $k_1$  remains constant for all pressure differences considered).

Equation (3) thus provides a means of checking the flow conditions through the cake. If equation (3) holds for all the pressure differences used, it can be safely concluded that in each case the flow is viscous and that  $n$ ,  $L$  and  $D$  are constant throughout the pressure changes.

### EXPERIMENTAL

*Apparatus.*—The experiments were carried out with the apparatus shown in Fig. 3. The apparatus consists essentially of a long glass tube F.T. with a brass extension piece attached to its end. The brass element contains a stainless steel gauze of 40 mesh. The glass tube F.T. is provided with a water jacket for maintaining constant temperatures.

(There are two communicating vessels CV1 and VC2, which receive supply of water at any desired temperature, and in turn supply water to the filter tube at constant heads, which can be adjusted with the help of U tube 'U').

### Procedure

(a) *Fixing Position of Filter tube.*—In the first instance (in Fig. 3), the stopper is not in the position as shown but is disconnected.

The space below gauze 'S' was completely filled with water by attaching a rubber tube and funnel to the nozzle at  $C_1$ , filling the funnel and tube with water and working it up and down to expel all the air. Then stop-cock ' $C_1$ ' was closed and filter tube F.T. filled up to the top with water and syphon 'A' was set, which connected F.T. with the communicating vessel 'CV1'. The three-way stop-cock was opened connecting it with 'U'. Then F.T. was adjusted until the water level coincided with mark 'H' on F.T. and mark ' $P_2$ ' on 'U'.

(b) *Filling of Filter tube with Pulp sample.*—Syphon 'A' was broken and the water in filter tube F.T. drained to an arbitrary level above the gauze. Stop-cock ' $C_2$ ' was closed. The sample to be tested was made into a good suspension and poured into the filter tube F.T., taking care to avoid the formation of air bubbles, while pouring. The suspension was then made up with water, approximately up to mark ' $H_2$ '.†

(c) *The Filter test.*—As soon as the sample had been completely washed into the filter tube F.T., a stop-watch was started and syphon 'A' was set on to the tube when the pulp had settled away from the top. After 5 minutes stop-cocks  $C_1$  and  $C_7$  were opened simultaneously and the rates of flow recorded until the flow rate became steady. The space below the gauze 'S' contained air, since it had been emptied of water when stop-cocks  $C_1$  and  $C_7$  were opened. The filtration took place therefore at a head  $P_2$ .

When a steady rate of flow has been reached, it is an indication that the pulp has

† The sample must be small enough to be completely washed into the filter tube F.T.

settled or in other words that the pulp has formed a cake of definite dimensions:

Before using this Filter test for comparing pulp of different degrees of beating, we have to ascertain, whether the different pulp samples after settling and applying different pressures fulfil equation (3).

The expression  $\frac{\Delta P_1 - \Delta P_2}{\Delta P_2 - \Delta P_3}$  is a function of  $\Delta P_1$ ,  $\Delta P_2$ , and  $\Delta P_3$ . These pressures have been kept constant through all our experiments. Therefore the above expression is constant.

For all our experiments this had the constant value of 6.06.

Table I shows how the value  $\frac{V_1 - V_2}{V_2 - V_3}$ , obtained from the flow rate measurements through cakes of guncotton pulp of different dry weights with filtered water\* at a temperature of 20° compares with the theoretical value 6.06.

The results obtained differ with the exception of sample 5† only in the second decimal from the theoretical value. It can therefore be assumed that for the practical purpose of a plant test, equation (3) is fulfilled. This means that laminary flow prevails and further that neither 'D', the average pore diameter nor  $n \times L$ , the total length of  $n$  pores of average diameter 'D' have noticeably changed during our experiments. However, it may be pointed out that the experiments have to be always started at the highest pressure and ended with the lowest pressure. The reason for this procedure is that in going from lower to higher pressures a noticeable compression of the cake takes place, but if the highest pressure is applied initially, the recovery (expansion) of the cake on lowering the pressure is practically negligible.

TABLE I

Sample.	Dry wt.	$V_1$ at $P_1$ .	$V_2$ at $P_2$	$V_3$ at $P_3$ .	$V_1 - V_2$ .	$V_2 - V_3$ .	$\frac{V_1 - V_2}{V_2 - V_3}$ .	$\frac{P_1 - P_2}{P_2 - P_3}$ .
1	33.6	33.4	13.5	10.2	19.9	3.3	6.00	6.06
2	22.12	49.6	20.0	15.2	29.6	4.8	6.1	6.06
3	28.6	37.0	15.0	11.4	22.0	3.6	6.1	6.06
4	36.56	31.0	12.7	9.6	18.3	3.1	5.9	6.06
5†	21.13	48.2	19.6	15.0	28.6	4.6	6.2	6.06
6	33.28	35.0	14.2	10.8	20.8	3.4	6.1	6.06

To determine the relative particle size in pulp, by correlating the average diameter of the capillaries with the average particle size equation (2) should be considered.

The right-hand side of equation (2) contains a second variable besides  $D$ , namely  $L$ , the length of the imaginary capillary, which is independent of particle size.

$L$  can be assumed to vary proportionately to the thickness of the cake in the filter tube and consequently to its dryweight. This assumption is actually already inherent in

\* The deviations are much bigger if unfiltered water is used.

† Sample 5 was taken after adding calcite. The calcite affects the capillary structure of the cake at different pressures.

this method of dealing with the cake as if it consisted of  $n$  capillaries with the average diameter  $D$  and the length  $L$ .

Therefore  $L = k_2 W$ , where  $k_2$  denotes a constant and  $W$ , the dryweight of the sample, substituting  $k_2 W$  for  $L$  in equation (2)

$$V = \frac{n\pi D^4 \Delta P \cdot g}{128\mu k_2 W} \quad \dots (2a)$$

$$V \cdot W = \frac{n\pi D^4 \Delta P g}{128\mu k_2} \quad \dots (2b)$$

The right-hand side of the equation (2b) is constant for any particular pulp, if the experiments are carried out at a constant temperature and pressure.

In practice it is very difficult to keep  $P$  constant for consecutive samples of G.C. as the thickness of the cake varies with  $W$ , its weight. This difficulty can, however, be overcome by determining the rate of filtration at two different pressure differences for each sample.

Assuming that the experiments are carried out with pressure differences  $P_1$  and  $P_2$ , then

$$V_1 \cdot W = \frac{n\pi D^4 \cdot \Delta P_1 \cdot g}{128\mu k_2}, \quad V_2 \cdot W = \frac{n\pi D^4 \cdot \Delta P_2 \cdot g}{128\mu k_2}$$

$$(V_2 - V_1)W = \frac{n\pi D^4 g}{128\mu k_2} (\Delta P_2 - \Delta P_1) \quad \dots (2c)$$

The pressure difference  $\Delta P_2 - \Delta P_1$  can be directly read at the U tube of our apparatus (Fig. 3). The dry weight was determined by the density bottle method.

For carrying out quick plant-tests it is generally not possible to maintain the temperature strictly constant, and the results have to be corrected. Apparently the only factors in equation (2c) which are affected by temperature are the viscosity coefficient,  $\mu$  and the pressure difference,  $\Delta P_2 - \Delta P_1$ . The latter is affected by the change in density with the temperature of the filtering liquid. In the temperature range proposed for conducting experiments, the change in density of the filtering liquid (water) is so small that it can be neglected. The change of viscosity, however, is appreciable.

It can be seen from equation (2c) that the rates of flow at different temperatures have to be inversely proportional to the viscosity coefficients at the particular temperatures.

*Effect of Temperature on Rates of Filtration.*—Under laminary flow conditions the rates of flow at different temperatures are inversely proportional to the viscosities corresponding to the temperatures.

$t_1^\circ$  = Temp. of water.  $\mu_1$  = Viscosity coeff. of water at  $t_1^\circ$ .  $V_1$  = Rate of flow of water at  $t_1^\circ$ .  $t_2^\circ$  = Temp. of water at  $t_2^\circ$ .  $\mu_2$  = Viscosity coeff. of water at  $t_2^\circ$ .  $V_2$  = Rate of flow of water at  $t_2^\circ$

$$V_1 \text{ (at } t_1^\circ) = \frac{n\pi D^4 \cdot \Delta P_1 \cdot g}{128\mu_1 k_2 W}, \quad V_2 \text{ (at } t_2^\circ) = \frac{n\pi D^4 \cdot \Delta P_1 \cdot g}{128\mu_2 k_2 W}$$

$$\frac{V_1}{V_2} = \frac{n\pi D^4 \Delta P_1 g}{128\mu_1 k_2 W} \times \frac{128\mu_2 k_2 W}{n\pi D^4 \Delta P_1 g} = \frac{\mu_2}{\mu_1} \therefore V_2 = V_1 \times \frac{\mu_1}{\mu_2}$$

In our experiments rates of flow have been corrected to 20°.

### *Some Results of Plant Experiments*

For practical purposes the rates of flow through a cake of guncotton pulp in standard state of packing have to be correlated to the average particle size.

The rates of flow depend upon number  $n$ , average diameter  $D$ , and length  $L$  of capillaries in the assemblage of guncotton particles in a standard state of packing. On the other hand,  $D$  and  $L$  determine the specific surface area of the guncotton cake and it now remains to correlate particle size with surface area. Fig. 2 shows the distribution of guncotton particles obtained by microscopic measurements after different times of beating. As already mentioned, the length of the fibres was determined by measuring the length of the circumscribed rectangle around each particle. If we consider a bigger particle, it is obvious that in general the length of the circumscribed rectangle cannot be correlated to its specific surface area. The same length would be measured whether the particle consisted of one single fibre or of an agglomeration of fibres with a much larger surface area. Fortunately the position is not so unfavourable when the great number of particles involved in the process of beating is considered. Whatever the shortcomings of the microscopic measurements described above may be, the fact remains that the fraction of particles of small size, counted under the microscope, increases with the time of beating (*vide* Fig. 2 and Table II).

The increase of the fraction containing small fibres, compared with the fractions with bigger fibres, implies an *increase of specific surface area with the time of beating*, since any kind of breaking up of particles into smaller ones can only have this result. In this investigation we are not interested in the particle size of a single individual fibre but in the average size of a great number of particles. As the *average particle* size decreases, the specific surface area increases and in this fact lies the justification for correlating the rates of flow determined by the filtration method with the average particle size of guncotton assemblage determined by microscopic measurement.

TABLE II\*

Dutation of beating (hrs.)	3½	3¼	4	4¼	4½	4¾	5	5¼	5½	5¾	6
% Frequency of particles of sizes below 0.062 mm.	13.8	23.4	41.2	50.0	51.9	58.9	60.8	73.2	80.1	90.3	95.3

\* Experiments carried out with small experimental beater.

In other words the figure  $W.V.$  (dry weight of guncotton cake  $\times$  rate of flow) can legitimately be taken as a measure of the degree of fineness of the pulp.

In our practical plant experiments we have used the expression  $(V_2 - V_3)k(\mu z / \mu^{20}) \times W$  as measure of the fineness.

$V_2$  and  $V_3$  denote rates of flow at pressure  $P_2$  and  $P_3$  respectively;  $W$ , dryweight;  $k$ , instrument factor 10;  $\mu z$ ,  $\mu$  at expt. temperature and  $\mu^{20}$ ,  $\mu$  at 20°.

Table III shows some results of plant experiments with three different beaters. These indicate the possibilities of the filtration test in following the effect on fibre size of beating in an individual beater, and also in comparing the working of different beaters.

It is possible by controlling the process of beating with our apparatus to obtain pulp of the correct fineness and to decrease the average beating time. Further, any defect of wear and tear on the beaters affecting the process is indicated by abnormal results. The experiments were all carried out with the apparatus shown in Fig. 2.

For routine plant tests a simplification is suggested as shown in Fig 4, which is self explanatory.

TABLE III

Temp. of pulp = 20°.

Duration of beating.	Beater No. 7		Beater No. 8		Beater No. 9	
	$(V_2 - V_3)W \times 10.$	$(V_2 - V_3)W \times 10(\mu_2/\mu_1).$	$(V_2 - V_3)W \times 10.$	$(V_2 - V_3)W \times 10(\mu_2/\mu_1).$	$(V_2 - V_3)W \times 10.$	$(V_2 - V_3)W \times 10(\mu_2/\mu_1).$
3½ hrs	1199	1199	1118	1118	1116	1116
3½	1023	1023	890	890	965	965
4	968	968	840	840	885	885
4½	883	886	880	825	936	853

The experiments were carried out in the Cordite Factory, Aruvankadu, Guncotton Section, between 1943 and 1945.

Our thanks are due to Mr. H. E. Page, O.B.E., I.O.S., Superintendent, Cordite Factory, Aruvankadu, for giving permission to carry out this work and for the encouraging interest he has shown in its progress.

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GUNCOTTON SECTION,  
CORDITE FACTORY,  
ARUVANKADU, 4

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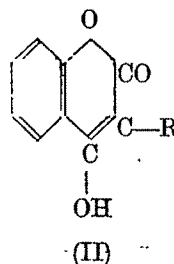
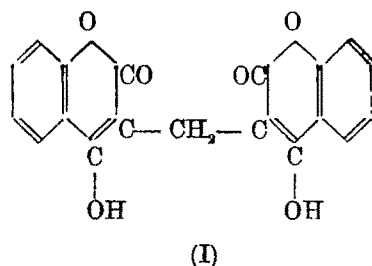
# SYNTHETIC INVESTIGATIONS IN THE HYDROXY-COUMARIN SERIES

## PART I. A GENERAL METHOD FOR THE SYNTHESIS OF 4-HYDROXYCOUMARINS

By K. C. GHOSH\*

A general method for the synthesis of 4-hydroxycoumarins has been described

After the identification by Link *et al* (*J Biol. Chem*, 1924 138, 21, 513, 529 ; 1928, 142, 941) of 3:3'-methylene-bis (4-hydroxycoumarin) (I) as the active agent causing haemorrhage of the cattle, fed on spoiled sweet clover hay and the discovery of the general anticoagulant properties of 3-alkyl-4-hydroxycoumarins, these compounds are looked upon as potent drugs in cases of thrombosis. As such, attempts (Link *et al.*, *J. Amer. Chem. Soc.*, 1943, 65, 2285, 2288, 2292 ; 1944, 66, 656, 900, 906) are being made to investigate their chemistry and also the synthetic routes by which those compounds can be prepared.



In the following lines, has been described, a method for the synthesis of 3-methyl-4-hydroxycoumarin (II, R=Me) which offers possibilities of syntheses of other similar (R=an alkyl radical) compounds.

Acetylsalicylic acid is condensed through its acid chloride in the cold with the sodio-salt of methyl malonic ester. The resulting acetylsalicyl-methylmalonic ester is hydrolysed with very dilute sulphuric acid ( $p_H=1$ ) by refluxing for 6 hours. On cooling, crystals of 3-methyl-4-hydroxycoumarin (II, R=Me) separate : these on recrystallisation from dilute alcohol melt at 226-27° (Lit. m.p. 227-28°, Satahman, Wolff and Link, *J. Amer. Chem. Soc.*, 1943, 65, 2285)

The very mild hydrolysing agent like dilute sulphuric acid of  $p_H 1$  has been tried purposely as we wish to utilise these conditions for synthesis of compounds containing sensitive radicals in the 3 position of the coumarin ring.

## EXPERIMENTAL

*Acetylsalicylic acid* was prepared by the following method (*cf.* Kaufmann, *Ber.* 1909, 42, 3482).

A mixture of salicylic acid (30 g.), acetic anhydride (50 g.), dry benzene (600 c. c.) and a few drops of pyridine was refluxed for 3 hours in a flask fitted with a condenser and

\* Since deceased.

a guard tube. 400 C. c. of benzene were distilled off and the residue in the flask was allowed to crystallise overnight. The crystals were filtered and washed with benzene and dried, m.p. 128°. On repeated crystallisations from benzene, it melted at 133°, yield 40 g.

*Acetylsalicyl Chloride.*—Acetylsalicylic acid (10 g.) was converted to its acid chloride, (b. p. 135°/12 mm.) by the usual thionyl chloride (6 c. c.) method, yield 8.4 g.

*Ethyl Acetylsalicyl-methylmalonate.*—Methylmalonic ester (8 g., prepared by condensing ethyl propionate with oxalate, followed by pyrolysis) was dropped on to 1.1 g. of molecularised sodium in dry benzene in the cold and kept overnight to form the sodio-salt. Acetylsalicyl chloride (8.4 g.) was then added in the cold with shaking when the reaction mass set as a jelly and kept as such for 6 hours and then refluxed on a water-bath for 2 hours. On cooling, it was diluted with excess of cold water, extracted with benzene, washed with sodium bicarbonate solution and then with water, and benzene was removed. The residue in the flask was distilled and the fraction boiling at 198°/4 mm. was collected, yield 5 g. (Found: C, 60.9; H, 5.96.  $H_{17}C_{20}O_7$  requires C, 60.7; H, 5.95 per cent).

*3-Methyl-4-hydroxycoumarin* (II, R = Me).—Ethyl acetyl salicyl-methylmalonate (4 g.) was refluxed with dilute sulphuric acid ( $p_H$  1, 40 c. c.) for 8 hours. After cooling, white crystals separated which were filtered off and dried on a porous plate to remove any adhering oil. On recrystallisation from dilute alcohol, it melted at 226–27°. (Found: C, 68.2; H, 4.53.  $C_{10}H_8O_3$  requires C, 68.2; H, 4.54 per cent).

Thanks are due to Prof. P. C. Mitter and Prof. S. N. Bose for their kind interest and to Dr. D. K. Banerjee for generous help. Thanks are also due to Mr. N. Ghosh for the microanalyses of the compounds.

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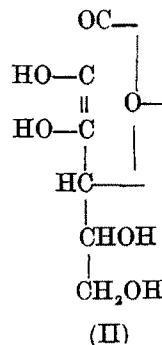
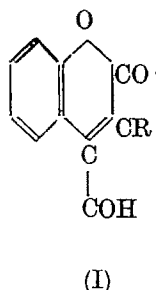
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# SYNTHETIC INVESTIGATIONS IN THE HYDROXY-COUMARIN SERIES. PART II. SYNTHESIS OF 3:4-DIHYDROXYCOUMARIN

K. C. GHOSH\*

Syntheses of 3:4-dihydroxycoumarin and 3-ethoxy-4-hydroxycoumarin have been described.

The 3-alkyl-4-hydroxycoumarins (I, R=alkyl) possess anticoagulant properties, whereas ascorbic acid (II) is strongly coagulant. The physiological properties of the compound (I, R=OH), which possesses the diolic system- $\text{C}=\text{C}(\text{OH})-\text{CO}-$  of the ascorbic acid would no doubt prove interesting to investigate. These considerations led to the finding out of a synthetic route for the preparation of 3:4-dihydroxycoumarin (I, R=OH).



Acetylsalicyl chloride has been condensed with acetoxymalonic ester to yield acetylsalicyl-acetoxymalonic ester, which on hydrolysis with caustic soda in methyl alcohol (Ghosh, *J. Indian Chem. Soc.*, 1946, 23, 401) in nitrogen atmosphere was expected to yield the compound (I, R=OH), but instead, salicylic acid (m. p. 158°) was obtained.

Next acetylsalicyl chloride was condensed with ethoxymalonic ester to yield acetylsalicyl ethoxymalonic ester, which on hydrolysis with sulphuric acid ( $p_u$  1) yields 3-ethoxy-4-hydroxycoumarin (I, R=OEt). Attempts to de-ethylate (I, R=OEt) with different reagents have failed yielding salicylic acid.

Finally acetoxyacetyl chloride has been condensed with ethyl salicylate in presence of pyridine. Ethyl acetoxyacetylsalicylate undergoes internal Claisen condensation in presence of molecularised sodium or potassium and on acidification with sulphuric acid yields (I, R=OEt), m. p. 226-28° (decomp).

## EXPERIMENTAL

*Ethyl Acetylsalicyl-acetoxymalonnate*.—Ethyl acetoxymalonnate (10 g.) was slowly dropped on 1.05 g. of molecularised sodium in benzene in the cold and kept for 6 hours when

\* Since deceased.

all sodium reacted and went into solution. Acetylsalicyl chloride (9 g.) was slowly added to the sodio-salt in the cold. A jelly-like mass was formed which was kept overnight and then refluxed on a water-bath for 2 hours. It was treated with excess of water, extracted with benzene, washed with sodium bicarbonate solution and then with water; the solvent was removed and the residual liquid was distilled at  $210^{\circ}/5$  mm. when slight decomposition took place, yield 8.2 g. (Found : C, 56.6; H, 5.23  $C_{18}H_{20}O_8$  requires C, 56.8; H, 5.26 per cent).

*Hydrolysis of Acetylsalicylacetoxy malonic Ester.*—(a) The ester (5 g.) was refluxed with sodium hydroxide (1.5 g. NaOH in 4 c.c. water) in methyl alcohol in nitrogen atmosphere. On cooling sodium salt separated out. The sodium salt was filtered, washed with methyl alcohol, dissolved in water, acidified with dilute sulphuric acid, the solution extracted with ether, ether removed and the residue was kept in a vacuum desiccator. Stars of needle-shaped crystals were obtained. These on recrystallisation from benzene melted at  $158^{\circ}$  (mixed m. p. with salicylic acid).

(b). The ester (9.8 g.) was similarly hydrolysed with sodium hydroxide (3 g. NaOH in 2.4 c. c. water) in methyl alcohol and the resulting sodium salt was dissolved and acidified in the cold. The solution was kept in the cold for 1 hour and then refluxed over a small flame for 1 hour in nitrogen atmosphere to ensure the elimination of carbon dioxide from the malonic acid system. The solution was cooled and similarly extracted as described in (a). The product was identified as salicylic acid.

(c) The ester (3.1 g.) in methyl alcohol was added to sodium methoxide (0.76 g. sodium) in methyl alcohol. The mixture was cooled in ice and then 0.6 c. c. of water was added and kept overnight in nitrogen atmosphere and then refluxed for 2 hours on a water-bath in an atmosphere of nitrogen. The sodium salt which separated on cooling was treated as described in (a) and (b). The product, however, was found to be salicylic acid.

(d). The ester (2 g.) was refluxed for 6 hours with a mixture of acetic acid (20 c.c.), hydrochloric acid (10 c. c.) and water (2 c. c.) in an atmosphere of nitrogen. On cooling crystals separated; these were identified as salicylic acid.

(e). The ester (2 g.) was refluxed with sulphuric acid (8%. 25 c. c.) On cooling, crystals separated which were found to be salicylic acid.

(f). The ester (2 g.) was refluxed for 20 hours with sulphuric acid ( $p_n$  1) and the crystals which separated on cooling were identified as salicylic acid. Similar treatment with still more dilute sulphuric acid (viz. of  $p_n$  2 and 3) resulted in the formation of salicylic acid.

*Ethyl Ethoxymalonnate.*—Ethyl chloracetate (57 g.) was condensed with sodium ethoxide (10.6 g. sodium in 150 c. c. alcohol) to form ethoxyacetic ester (40 g.) b. p.  $156^{\circ}$ .

Ethyl oxalate (41 g.) was added to cooled (freezing mixture) sodium ethoxide (4 g. sodium, 10 c. c. alcohol) in dry benzene and was thoroughly mixed. The ethoxyacetic ester (40 g.) was added drop by drop with shaking and the mixture kept for 48 hours. The reaction product was treated with cold water, the aqueous layer after acidification was worked up. The crude material was pyrolysed at  $180^{\circ}$  for 4 hours and the residue distilled at  $220-225^{\circ}$ , yield 16 g

*Ethyl Acetylsalicyl ethoxymalonate*.—Acetylsalicyl chloride (22 g.) was condensed with the sodium salt (2.4 g. sodium) of ethoxymalonic ester (21 g.) in dry benzene. The reaction product on being worked up in the usual way distilled at 180-85°/5 mm. as a semisolid liquid, yield 20 g. (Found: C, 59.2; H, 5.98.  $C_{18}H_{22}O_6$  requires C, 59.0; H, 6.01 per cent).

*3-Ethoxy-4-hydroxycoumarin* (I, R=OEt).—The above condensation product (15 g.) was refluxed for 32 hours with sulphuric acid ( $p_H$  1, 200 c. c.). On cooling, white crystals separated. These were filtered, dried on a porous plate and crystallised twice from dilute alcohol, m. p. 112° (m. p. of the sample dehydrated by heating in vacuum at 60°, 126°), (Found: C, 63.9; H, 4.90.  $C_{11}H_{10}O_4$  requires C, 64.5; H, 4.88 per cent).

The compound is soluble in sodium bicarbonate, but has no reducing properties towards silver nitrate, iodine, indophenol blue etc. It gives no coloration with ferric chloride.

*De-ethylation of* (I, R=OEt).—(a) 3-Ethoxy-4-hydroxycoumarin (0.5 g.) was refluxed with dilute hydrochloric acid (1:1, 11 c. c.) for 12 hours and then extracted with ether. The ethereal layer was washed with sodium bicarbonate solution and the bicarbonate solution was acidified in the cold when white crystals (m. p. 98-111°) were obtained. These on recrystallisation from dilute alcohol melted at 111-12° and was identified with (I, R=OEt).

(b) 3-Ethoxy-4-hydroxycoumarin (1 g.) was refluxed with acetic acid-hydrochloric acid (1:1, 20 c. c.) mixture for 8 hours and was worked up as usual. The product was found to be a mixture of (I, R=OEt) and salicylic acid.

(c) 3-Ethoxy-4-hydroxycoumarin (1 g.) was refluxed with concentrated hydrochloric acid (20 c. c.) for 4 hours. On cooling, crystals of salicylic acid separated.

*Acetoxyacetyl Chloride*.—Glycollic acid was prepared by the prolonged refluxing of a solution of potassium chloroacetate in water, then evaporating the solvent to dryness on a water-bath and extracting the dry mass with acetone and removing the solvent first on a water-bath and then in vacuum. Glycollic acid (42 g.) was next converted into acetoxyacetic acid (144-45°/12 mm.) by reacting in the dry state with acetyl chloride first in the cold and then on a water-bath for 1 hour, yield 31 g.

Acetoxyacetic acid (30 g.) was converted into its acid chloride (55-60°/10 mm.) with thionyl chloride (19 c. c.), yield 30 g.

*Ethyl Acetoxyacetylsalicylate*.—Acetoxyacetyl chloride (24.2 g.) was dropped on a mixture of ethyl salicylate (30 g.) and pyridine (15 g. cooled in a freezing mixture) and kept overnight and then heated on a water-bath for 1 hour. The reaction mixture was diluted with excess of cold water, extracted with benzene, washed with dilute hydrochloric acid and sodium bicarbonate solution and then with water, benzene removed and distilled, b. p. 181°/8 mm., yield 35 g. (Found: C, 58.7; H, 5.28.  $C_{13}H_{14}O_6$  requires C, 58.6; H, 5.26 per cent).

*3:4-Dihydroxycoumarin* (I, R=OH).—The above condensation product (21 g.) was added to sodium dust (3.2 g.) in dry benzene and refluxed on a water-bath till all sodium went into solution. It was then cooled in ice and excess of ice-water containing calculated quantity of acid was poured into the reaction mixture. It was extracted with benzene and after removal of benzene, the residue was kept in a vacuum desiccator, when crystals

separated. These were dissolved in alcohol, charcoaled and filtered. The alcohol was removed from the solution and the solid left was recrystallised from benzene-alcohol mixture, m. p. 226-28° (decomp). (Found : C, 60.6 ; H, 3.42.  $C_9H_8O_4$  requires C, 60.7 ; H, 3.37 per cent).

The above internal condensation can be achieved also with molecularised potassium. The high temperature technique of Link *et al.* (*J. Amer. Chem. Soc.*, 1943, 65, 2285) for carrying out this reaction was found to give poorer yield.

This compound gives an intense green coloration which vanished rapidly with ferric chloride, a reddish coloration with uranium salts, reduces indophenol blue, silver nitrate, potassium permanganate etc., instantaneously in the cold and in sodium bicarbonate solution it reduces iodine quantitatively.

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## OBSERVATIONS ON THE ENZYME SYSTEM INVOLVED IN THE OXIDATION OF GLUCOSE TO GLUCONIC ACID BY *A. NIGER*

By S. K. Bose

Aerobic and anaerobic oxidation of glucose by enzyme preparation of *A. niger* in presence of hydrogen acceptor has been investigated. Specificity of the enzyme and the effect of inhibitors on the reaction have also been studied.

Behaviour of the living mould has been studied both under aerobic and anaerobic conditions and in presence of hydrogen acceptors and KCN as inhibitor.

The two component theory of oxidation of glucose in which the enzyme system is supposed to consist of dehydrogenase and a specific glucose oxidase is confirmed and the oxidase is considered to be distinct from cytochrome oxidase.

The production of gluconic acid as a result of microbial activity has long been known. Muller (*Biochem.Z.*, 1928, 199, 136) was the first to make an effort to explain the mechanism of the formation of the acid. He prepared an extract by subjecting a mixture of the mycelium, sand and kieselguhr to a pressure of 300 atmospheres. Muller (*ibid.*, 1929, 205, 111; 1929, 213, 211) further concentrated it by precipitation with 96% alcohol or alcoholic ether mixture. He studied the properties of the preparation and obtained gluconic acid by oxidation of glucose with this extract and according to him the enzyme preparation contained glucose oxidase, different from Warburg's respiratory enzyme. Later on, he (*Naturwiss.*, 1940, 28, 516) found the enzyme preparation to consist of two parts—an oxytropic dehydrogenase and an anoxytropic dehydrogenase, to which 2:4-dichlorophenol-indophenol could act as the hydrogen acceptor. Franke *et al* (*Annalen*, 1937, 582, 1) separated from *A. niger* and *P. glaucum*, an enzyme which functioned as glucose dehydrogenase and oxidised glucose to gluconic acid and was cyanide-insensitive; molecular oxygen and methylene blue could act as hydrogen acceptors. Later, Franke *et al.* (*Annalen*, 1939, 541, 117) discovered glucose oxidase from *A. niger*, *P. glaucum*, and cytomyces. Subsequently he developed a method for its isolation and studied its properties, and termed it a flavin enzyme. Yasuyuki Ogura (*Acta Phytochim. Japan*, 1939, 11, 127) obtained from moulds, grown on synthetic media, an enzyme which he named glucose dehydrogenase. Methylene blue and also molecular oxygen could not act as hydrogen acceptors for the enzyme but thionine, *o*-chlorophenol, quinone etc. could do so.

These dissimilar experimental evidences lead to the conclusion that the formation of gluconic acid is not due to a common principle present in all the strains of the moulds producing gluconic acid. It varies from strain to strain. The exact mechanism involved appears to depend almost solely upon the nature of the strain. Hence in the present investigation, the enzyme of a particular strain has been used. In a system containing a specific glucose dehydrogenase, the evidence to justify the existence of another "glucose oxidase", as postulated by Muller, needs further investigation. Since the apparent specificity of the aerobic function may result from the combined effects of (i) specific glucose dehydrogenase and (ii) non-specific molecular oxygen

activating system e. g., cytochrome-cytochrome oxidase. The effect of KCN upon the gluconic acid fermentation process may also throw light on the problem. The anaerobic formation of gluconic acid in presence of hydrogen acceptors is also another interesting point. It is also equally interesting to enquire how far the synthesis of cells is related to gluconic acid formation. These are a few aspects of the problem which require further elucidation to arrive at the enzymatic mechanism of gluconic acid formation.

### EXPERIMENTAL

Four days' old mycelial growth of a strain of *A. niger*, isolated in our laboratory, was used throughout and its metabolic habits were thoroughly investigated (Table I). The strain was grown on glucose medium consisting of glucose (150 g.),  $\text{KH}_2\text{PO}_4$  (0.6 g.),  $\text{MgSO}_4$  (0.5 g.), dibasic ammonium phosphate (1.4 g.), chalk (3.0 g) and water to make 2000 c.c. at  $p_H$  5.6 and at a temperature of  $32^\circ$ . This medium has been subsequently referred to as the glucose medium. In a typical experiment, the moist mycelium (80 g.) was washed 10 to 12 times into a total volume of 40 lbs of water and finally starved for 6 hours in normal saline in order to remove the remaining traces of glucose from the cell as far as possible. The mycelium was then dried over  $\text{CaCl}_2$  in a vacuum desiccator, wrapped with black paper to exclude light as far as possible. The dried mycelium was powdered and kept as stock in the desiccator under vacuum and away from light. For the day's experiment, a portion of the powder was taken in aqueous suspension to give a concentration of 25 mg. of dry mycelium per c.c.

TABLE I

*Metabolic habits of the strain of A. niger.*

Conc. of glucose soln. = 3.75 g. in 50 c.c. water. Incubation period = 7 days.  
 $p_H$  = 5.6. Temp. =  $32^\circ$ .

Metabolites	Yield of metabolite	Glucose equiv. of metabolites	
Gluconic acid	2 890 g	2 650 g	70.65%
Oxalic acid	0 003	0 002	0.04
Citric acid	0 030	0 028	7.75
Carbon dioxide	0 177	0 121	3.23
Mycelium	0 544	0 498	13.27
Unreacted glucose	—	0 260	6.93
Total	3 644	3 559	94.87

This suspension was mechanically shaken and used as the source of enzyme in experiments with Warburg's apparatus. For experiments with the Thunberg tube, the dried mycelium powder was ground up with one third its weight of washed sea-sand in a ground glass mortar mixed with water to give a suspension a strength of 50 mg. of the mycelium per c.c. and shaken for  $\frac{1}{2}$  hour mechanically and centrifuged. The centrifugate was used as the source of enzyme in experiments with Thunberg tube, as the use of mycelium suspension as such prevented the accurate judgment of the colour change in the Thunberg tube.



Different substrates were tried including glucose and sodium salt of acids like gluconic, malic, succinic, and pyruvic. The inhibitors tried were KCN, NaF, chlorotone and urethane. The hydrogen acceptors used in the Thunberg tube were methylene blue and 2:6 dichlorophenol-indophenol.

*Experiments with the Warburg's apparatus and Thunberg tube.*—The aerobic activity of the mycelium suspension was measured manometrically in Warburg's apparatus. Necessary controls were kept in all cases. The composition of the contents of the flasks was as shown in Table II, A.

TABLE II

A. Warburg apparatus.		B. Thunberg tube.	
Mycelium suspension (50 mg./c.c.)	.. 0.8 c.c.	Phosphate buffer (pH 6.5)	.. 1.0 c.c.
Phosphate buffer (pH 6.5)	.. 1.0	Dye soln. (12.5 mg./100 c.c.)	.. 0.4
Substrate solution (4.5 M/32)	.. 0.4	Substrate (4.5 M/32)	.. 0.4
Water or inhibitor (6 mg./c.c.) or dye solution (12.5 mg./100 c.c.)	0.8.	Enzyme soln. (25 mg. of dried mycelium per c.c.)	0.8
		Inhibitor (6 mg./c.c.)	
Total volume	.. 3.0 c.c.	or distilled water.	.. 0.4
Temp.	.. 37.5°	Total volume	.. 3.0
		Temp.	.. 37.5°

The anaerobic activity of the extract was measured by Thunberg technique with 2:6-dichlorophenol indophenol and methylene blue as hydrogen acceptors. The composition of the contents of the Thunberg tube was as shown in Table II, B, unless otherwise stated.

*Estimation and Identification of Gluconic Acid.*—Gluconic acid was identified as the phenylhydrazine derivative and by determining the mixed melting point with an authentic specimen of gluconic acid phenylhydrazone. Gluconic acid was estimated both by macro and micro methods. In the macro method the calcium gluconate formed was estimated *via* calcium oxalate (May *et al.*, *Ind. Eng. Chem.*, 1934, 26, 575) and in the micro method gluconic acid formed was estimated directly by titration with standard alkali.

*Formation of Gluconic Acid from Glucose by the Dried Mycelium.*—The dried mycelium (0.5 g.) was added to 50 c.c. of sterile medium containing the usual nutrients and a few drops of toluene, and the mixture was incubated for 48 hours. The medium was analysed thereafter. An yield as high as 80% of gluconic acid on the basis of glucose taken was reached.

*Quantitative Relation between the Glucose used and Gluconic acid formed and Oxygen utilised.*—These relations were established with the aid of the Warburg's manometer (Table III); 10.125 mg. of glucose were initially employed.

TABLE III

No. of expt.	Glucose consumed.	Gluconic acid formed.	Oxygen used.	Glucose used on the basis of O <sub>2</sub> utilised.	Gluconic acid formed on basis of O <sub>2</sub> utilised.
1.	3.36 mg.	3.70 mg.	0.30 mg.	3.38 mg.	3.68 mg.
2.	2.88	3.12	0.25	2.81	3.06
3.	2.85	3.20	0.26	2.92	3.19
4.	3.05	3.46	0.28	3.15	3.43

The actual and calculated values were well within the limits of experimental error. Thus quantitative conversion of glucose disappearing into gluconic acid confirms the earlier observations of Muller and others made with the strains of *A.niger*. This would indicate that probably all gluconic acid producing strains of *A.niger* have this ability for quantitative conversion.

*Specificity of the dried Mycelium.*—The enzymic character of the reaction is evidenced by its specificity. The reaction was tried with substrates like fructose, gluconate, oxalate, succinate and malate in the Warburg's apparatus. The results are shown in Table IV.

TABLE IV

Enzyme=50 mg./c.c. In case of glucose as a substrate, only 10 mg. per c.c. were used.

Substrates.	Oxygen absorbed in mm. <sup>3</sup> at N.T.P. during					
	0 min.	15 min.	30 min.	45 min.	60 min.	75 min.
Fructose	0	2	5	7	7	8 c.c.
Gluconate	0	1	3	4	5	5
Oxalate	0	0	2	3	4	5
Succinate	0	3	4	4	5	6
Malate	0	2	4	5	6	7
Glucose	0		45	60	72	86

The results show the specificity of the enzyme system present in the dried mycelium for the oxidation of glucose to gluconic acid.

*Thermolability of the Preparation.*—The preparation of the enzyme was exposed to different constant temperatures for 30 minutes and then its activity measured in terms of oxygen absorption. The results show the thermolability of the enzyme and the thermal death point to be about 72°.

*Optimum  $p_H$*  for the reaction was determined in the usual way. The results show the optimum  $p_H$  to be about 6.5. It should be noted in passing that it is a case of optimum  $p_H$  range rather than that of optimum  $p_H$ .

#### *Anaerobic Experiments.*

The anaerobic behaviour of the enzyme extract was studied in Thunberg's tube with glucose as the substrate. Methylene blue and 2:6-dichlorophenol-indophenol were used as hydrogen acceptors. The intervals after which 40%, 60% and 80% decolorisation took place were determined (cf. Quastel, *Biochem. J.*, 1924, 18, 519). The results were found to be negative with respect to the former dye, and positive to the latter.

Methylene blue was as rapidly reduced with glucose as without it. But the presence of glucose very appreciably diminished the reduction time of the 2:6-dichlorophenol-indophenol.

*Nature of the Dehydrogenation Product of Glucose by dried Mycelium in presence of Hydrogen Acceptor.*—To identify the product of this dehydrogenation as gluconic acid

the previous experiment was repeated under anaerobic condition with the medium comprising ingredients normally employed, along with one or other of the hydrogen acceptors like the sodium salts of malic, lactic, and pyruvic acid (*cf. Wood et al. Biochem. J.*, 1937, 31, 349). The technique of maintaining the anaerobic condition consisted in conducting the fermentation in small Erlenmeyer flasks which were evacuated inside a desiccator and refilled with nitrogen to a pressure slightly less than that of the atmosphere. The results indicated incapacity of the dried mycelium to oxidise glucose to gluconic acid in complete absence of air, even in presence of hydrogen acceptors tried.

An effort towards this end was again made with the help of the Warburg's manometer using ferricyanide-bicarbonate technique (*Quastel et al., Biochem. J.*, 1938, 32, 930). The results are indicated in Table V.

TABLE V

*Glucose dehydrogenating activity by Warburg's manometer.*

System.	Oxygen absorbed in mm <sup>3</sup> at N.T.P. during							
	0 min.	25 min.	50 min.	75 min.	100 min.	125 min.	150 min.	175 min.
Enzyme only	0	8	13	18	24	28	31	35
Boiled enzyme+glucose	0	6	7	10	12	14	16	20
Enzyme+glucose	0	8	12	20	27	34	39	44
Boiled enzyme+glucose+dye	0	7	7	10	13	14	17	21
Enzyme+glucose+dye	0	8	12	20	28	34	40	44

No definite conclusion can be drawn from the above results, but it can be inferred that the dried mycelium did possess glucose dehydrogenating power, although it was not found possible to identify the product of dehydrogenation.

*Specificity of the anaerobic behaviour* was demonstrated by the inactivity of the preparation towards a number of substances as shown in Table VI A and Table VI B; 2:6-dichlorophenol-indophenol was used as the hydrogen acceptor.

TABLE VI A

System.	% Decolorisation		
	40%	60% Decolorisation time.	80%
Enzyme only	23 min.	34 min.	45 min.
Enzyme+glucose	11	16	21
Boiled enzyme+glucose	80	—	—
Enzyme+gluconate	32	48	63
Boiled enzyme+gluconate	87	—	—
Enzyme + fructose	22	33	43
Boiled + enzyme+fructose	82	—	—
Enzyme+glycerophosphate	42	66	87
Boiled enzyme+glycerophosphate	90	—	—
Enzyme+lactate	36	55	72
Boiled enzyme+lactate	85	—	—

TABLE VI B

System.	% Decolorisation		
	40%	60%	80%
	Decolorisation time		
Enzyme only	22 min.	34 min	45 min.
Enzyme+succinate	17	28	35
Boiled enzyme+succinate	69	—	—
Enzyme + malate	18	28	36
Boiled enzyme+malate	72	—	—
Enzyme+pyruvate	28	43	57.
Boiled enzyme+pyruvate	80	—	—
Enzyme+oxalate	90	—	—
Boiled enzyme+oxalate	94	—	—
Enzyme+glucose	11	16	21
Boiled enzyme+glucose	80	—	—

Both the tubes containing succinate and malate assumed a violet colour and hence the results obtained are not reliable.

*The  $p_H$  optimum for Anaerobic reaction.*—The optimum  $p_H$  for the anaerobic reaction was also determined following the usual procedure and was found to be nearly the same as that for the aerobic ( $p_H$  6.5). *Oxygen absorption in presence of 2:6-Dichlorophenol-indophenol.*—Warburg's apparatus was used in the usual way with the suspension of dried mycelium and glucose as substrate with 0.4 c.c. of a solution of 2:6-dichlorophenol-indophenol (25 mg./c.c.). The results (Table VII) indicate a definite fall in oxygen uptake in presence of the dye. This may be due to the poisoning of the enzymes concerned in the oxidation by the dye.

TABLE VII

Enzyme=50 mg./c.c. of the suspension.

Rate of oxygen absorption in mm.<sup>3</sup> at N.T.P.

No. of. expt.	In absence of dye in					In presence of dye in				
	0 min.	10 min.	15 min.	20 min.	25 min.	0 min.	10 min.	15 min.	20 min.	25 min.
1.	0	94.0	132.0	165.6	196.8	0	62.4	88.8	114.0	139.2
2.	0	92.8	130.2	162.8	194.0	0	66.0	93.8	118.4	144.0
3.	0	96.0	138.8	166.0	200.0	0	58.0	90.0	110.8	136.4
4.	0	84.0	127.8	162.0	192.4	0	60.8	87.2	112.0	137.0

*Behaviour of the Living Mould under Anaerobic Conditions.*

*Effect of Anaerobiosis on the Growth of the Strain both in Presence and Absence of Hydrogen Acceptors.*—Three Erlenmeyer flasks of 250 c.c. capacity, each containing 50 c.c. of glucose medium which in one case contained one or other of the usual hydrogen acceptors and in another case contained none, were inoculated and incubated for 8 days under an anaerobic condition. After the incubation period was over, the flasks were examined

for growth. The flasks were re-exposed to air and further incubated for a period of 8 days and then analysed. In complete absence of air, no growth of the strain was observed in either cases, but anaerobiosis did not kill the organism at least within 8 days. So re-exposure to air caused growth, accompanied by the formation of gluconic acid (Table VIIIA). Absence of growth might be ascribed to the lack of energy required for growth, which in the present case resulted from the aerobic oxidation of glucose to gluconic acid. Hence absence of oxidation caused absence of growth. Moreover, anaerobiosis was found to have an unhealthy effect on the gluconic acid producing ability of the organism as evidenced from the lowering of yields (Table VIII A). It might also be stated that the hydrogen acceptors tried served no useful purpose (Table VIII A)

TABLE VIIIA

	Anaerobically exposed strain re-exposed to air.	Control strain.	Anaerobically exposed strain in presence of hydrogen acceptors re-exposed to air.
% Yield of gluconic acid on basis of glucose taken	69.2	84.3	66.5
% Glucose metabolised	82.4	98.0	83.9
Wt. of mycelial growth (in g.)	0.524	0.532	0.540

*Effect of Anaerobiosis on the Aerobic Growth of the Strain in presence of Hydrogen Acceptors.*—The strain was incubated aerobically for 4 days to obtain a luxuriant growth of the mycelium, which, after removing the original fermented liquor, was washed aseptically in saline and allowed to ferment for 4 days under anaerobic condition; an equal quantity of a fresh medium of identical composition, except that it contained some hydrogen acceptors in quantity equivalent to theoretically needed amount of oxygen to oxidise glucose taken to gluconic acid. The results are given in Table VIIIB. Another set of experiments was carried out exactly in the same way except that the aerobic growth after anaerobic incubation for 4 days was further incubated for 4 days in presence of air. The results are shown in Table VIII B).

TABLE VIII B

Glucose = 3.75g. in 50 c.c. medium.

Hydrogen acceptors used.	Wt. of mycelium from anaerobic expt.	% Yield of gluconic acid $\equiv$ glucose taken under anaerobiosis.	Wt. of mycelium on exposure to air.	% Yield of gluconic acid $\equiv$ glucose taken on exposure to air.
Malate (6.84 g.)	0.50 g.	0.0	0.82 g.	69.2
Lactate (4.66 g.)	0.53	0.0	0.84	70.9
Pyruvate (4.40 g.)	0.51	0.0	0.85	68.6

The data in Table VIII B indicate that even the aerobic growth could not produce gluconic acid anaerobically in presence of hydrogen acceptors tried. Re-exposure to air caused formation of gluconic acid and also the weight of mycelium formed was increased.

It may be stated thus that oxygen is essentially needed for the production of gluconic acid and that the formation of gluconic acid is accompanied by the synthesis of new cells, because the formation of fresh mycelium occurred even in presence of only 4 days' old mycelium for gluconic acid production.

#### *Inhibition Experiments*

The effect of inhibitors e. g. KCN, NaF, chloretone and urethane on the anaerobic action of the enzyme preparation upon glucose was studied in Thunberg's tube. None of the inhibitors except chloretone had any effect on the enzyme action (Table IX A). The inhibition experiments were also carried out in the Warburg's manometers with KCN solution concentration of which varied within wide limits and it was observed that the inhibition was not complete, but partial and constant within a wide range of cyanide concentration (of the order of 0.66%) (Table IX B). This inhibition constant, although independent of cyanide concentration, is dependent upon time. Thus with the progress of the reaction, the values of this inhibition constant for different periods, e. g., 10, 20, 30 and 40 minutes were respectively 0.66, 0.67, 0.70 and 0.71. This apparent disagreement in the values of the constant with time might be due to the presence of gluconic acid formed which would complicate the issue still further.

TABLE IX A

#### *Inhibition experiment with Thunberg's tube.*

System.	Percentage decolorisation.		
	40%	60%	80%
Enzyme alone	31 min.	46 min.	60 min.
Enzyme+glucose	15	26	35
Enzyme+glucose+KCN	15	26	35
Enzyme+glucose+chloretone	27	39	52
Enzyme+glucose+urethane	15	26	35
Enzyme+glucose+NaF	15	23	30

TABLE IX B

#### *Effect of KCN on oxidation in different concentration*

Enzyme=25 mg. per c.c.

System.	Time in minutes,					
	0	10	20	30	40	50
	(Oxygen absorption in mm. <sup>3</sup> at N.T.P.)					
Enzyme alone	0	1.0	2.0	4.0	5.0	6.0
Enzyme+glucose	0	64.0	99.2	126.6	157.5	176.2
Enzyme+glucose+KCN (2mg./c.c.)	0	54.6	91.4	119.4	149.6	168.4
Enzyme+glucose+KCN (4mg./c.c.)	0	52.0	88.2	115.6	144.8	161.4
Enzyme+glucose+KCN (6mg./c.c.)	0	42.0	66.4	90.2	114.0	122.8
Enzyme+glucose+KCN (8mg./c.c.)	0	43.4	67.0	92.0	115.2	125.0
Enzyme+glucose+KCN (10mg./c.c.)	0	42.2	67.0	90.0	112.6	124.0

These inhibition experiments, as represented in Tables IXA and IXB, indicate that the enzyme system of *A.niger* consists of two distinct enzymes viz., glucose oxidase and glucose dehydrogenase, each of them can function independently.

The inhibitor KCN seems to have no effect on the anaerobic action of the enzyme preparation on glucose (Table IX A), but since in presence of air, KCN reduces the oxygen uptake, it is of interest to enquire how far the gluconic acid production by the living fungus would also be affected by KCN. The question naturally arises how far this inhibitor affects the gluconic acid fermentation process by the living mould. The glucose medium was prepared with different concentrations of KCN, taken in conical flasks labelled A, B and C and then inoculated with the spores of the strain. Another set of experiments was conducted side by side in flasks D, E and F in which the mycelial mat was grown in a medium prepared without KCN for a few days and then allowed to ferment a fresh solution containing different concentrations of KCN. Growth was observed accompanied by the formation of gluconic acid as shown in Table X.

TABLE X

Name.	Conc. of KCN.	% Yield on glucose taken.	Name.	Conc. of KCN.	% Yield on glucose taken.
A	0.2 mg./c.c.	62.1	D	0.2 mg./c.c.	72.9
B	0.4	50.3	E	0.4	68.1
C	0.8	38.6	F	0.8	57.0

The presence of cyanide did not stop the gluconic acid formation, but only lowered the yield (Table X). This can be readily explained if we assume that of the two factors involved in gluconic acid formation, only one was blocked by cyanide and thereby the yield was lowered, whilst the other functioned normally, unaffected by the presence of cyanide.

#### *Cytochrome Oxidase System.*

In order to test whether the cyanide-sensitive part in the glucose oxidation enzyme system is identical with or closely related to the cytochrome-cytochrome oxidase system, its behaviour towards *p*-phenylene diamine was studied. The results (Table XI) were negative. It appears therefore that this system is absent from the mycelium and consequently the cyanide-sensitive part of the enzyme system concerned in the oxidation of glucose is distinct from the cytochrome-cytochrome oxidase system. It is probable that this oxidase is specific for glucose.

TABLE XI

System.	0 min.	20 min.	40 min.	60 min.	80 min.	120 min.
Oxygen absorption mm. <sup>3</sup> at N.T.P.						
Enzyme alone	0	15	12	22	40	92
<i>p</i> -Phenylene diamine	0	22	39	57	90	186
Boiled enzyme + <i>p</i> -phenylene diamine	0	9	21	29	42	57
Enzyme + <i>p</i> -phenylene diamine	0	9	19	32	47	63

## DISCUSSION

The oxidation of glucose to gluconic acid in presence of oxygen by moulds is not due to a common principle; it depends on the nature of the particular strain of the mould concerned. In the particular strain under consideration, the properties of the dead mycelium preparation, in relation to its behaviour towards  $p_H$  and temperature and its marked specificity towards glucose, have been studied. The experiments in Warbur's manometer as well as in Thunberg's tube indicate that the oxidation may be due to one component (one component theory) or may be due to two components (two component theory) linked together for the same end. According to the first theory, the oxidation is due to glucose dehydrogenase to which both molecular oxygen and 2:6-dichlorophenol-indophenol can act as hydrogen acceptor. According to the second theory, the first of the two components is a glucose oxidising system composed of either a specific glucose oxidase (which requires molecular oxygen for its activity) or a non-specific molecular oxygen-activating mechanism like cytochrome-cytochrome oxidase; and the second component is a specific glucose dehydrogenase. In both the theories the existence of a glucose dehydrogenase is assumed, although it has not been possible to identify the product of glucose dehydrogenation as gluconic acid. But there are good reasons to believe that the product of anaerobic dehydrogenation is gluconic acid. Firstly, the anaerobic dehydrogenation of glucose is not inhibited by KCN, as also the certain fraction of aerobic oxidation, which results in the formation of a product, identical with gluconic acid. Secondly, the presence of KCN does not stop the formation of gluconic acid by the living strain of *A. niger*, but only lowers the yield which indicated that the path which was blocked and which was not by KCN led to the formation of gluconic acid. The fact that in our experiments KCN inhibits the oxidation and gluconic acid production not completely but only to a definite degree supports the two component theory. If only one dehydrogenase is involved, as in the one component theory, KCN should not have inhibited the oxidation at all or should have inhibited it completely. If there are two component enzyme systems, one of which is cyanide sensitive and the other cyanide-insensitive, then the partial but definite inhibition of oxidation produced by KCN is readily explained. The behaviour of the living strain towards KCN furnishes another evidence in support of the two component theory. The growth of the strain in presence of air is not inhibited by KCN, but the yield is lowered. This can be readily explained if we assume that of the two independent paths leading to the oxidation of glucose to gluconic acid, one viz., the aerobic path i.e., glucose oxidase was blocked, whilst the other is free to act. Consequently the yield is lowered instead of being completely inhibited. During the *in vivo* experiments there was hardly any gluconic acid formation nor any further increase in weight of the mycelium occurred, when the aerobic growth of the strain was incubated anaerobically even in presence of hydrogen acceptors. On the other hand, gluconic acid formation as also increase in weight of mycelium occurred when aerobic growths, after anaerobic incubation, was further incubated in presence of air. Thus the synthesis of cells is accompanied by the formation of gluconic acid.



The nature of the cyanide-sensitive oxidase component involved has been further studied and as it is unable to oxidise *p*-phenylene diamine, this glucose oxidase system appears to be distinct from the non-specific cytochrome-cytochrome oxidase system which readily oxidises *p*-phenylenediamine. In all probability, the oxidase system concerned is specific for glucose.

To summarise the above facts, it may be concluded that the oxidation of glucose to gluconic acid is due to both glucose oxidase and glucose dehydrogenase. They can act independently, but their effects are additive.

Glucose + glucose dehydrogenase  $\rightarrow$  Gluconic acid

Glucose + glucose oxidase  $\rightarrow$  Gluconic acid

Since both the enzymes have nearly the same  $p_H$  optima, the physiological conditions under which the fermentation process is carried out enable both of them (enzymes) to operate simultaneously for the oxidation of glucose to gluconic acid.

Grateful thanks of the author are due to Prof. B. C. Guha and Dr. B. N. Ghosh of Dept. of Applied Chemistry, University of Calcutta, for their kind interest and valuable

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## ON THE AMINO-ACIDS CONTENT OF LIVER PREPARATIONS

BY SISIR KUMAR GANGULY AND PRIYANATH SEN-GUPTA

The amino-acids as present in liver remain almost unchanged in a liver preparation made by enzymatic hydrolysis. The latter also promotes a better growth for *Lactobacillus casei* and is considered to be a better therapeutic medicament in cases where liver is indicated.

With the recent progress in the Science of nutrition, a food is no longer being taken for granted, but is actually used as a specific therapeutic measure in the treatment of disease. Liver is used as food and medicine for various purposes. Being rich in protein, minerals and vitamins, it is being found to be specially valuable in certain types of anaemia. In spite of its wider use, the active principles that are responsible for its therapeutic importance are not exactly known. Jacobson and Subbarow (*J. Clin. Invest.*, 1937, 16, 573) have shown that *L*-tyrosine that is present in liver does not play any part but this with incorporation of other factor, which is of a polypeptide nature, enhances the physiological property of liver in pernicious anaemia. A most recent addition to the group of purified nutritional substances is the use of a mixture of various essential amino-acids as a source of protein food. Liver would accordingly be better utilised, if its protein be fractionated to its component parts by suitable hydrolysis. As a matter of fact, a proteolysed liver preparation (cf. Davis, Davidson, Riding and Shaw, *Brit. Med. J.*, 1943, i, 656) containing fragmented molecules of liver protein along with its accessory growth factors, is being found to be superior in the treatment of various types of anaemias. Mapson (*Biochem. J.*, 1932, 26, 970) has shown that the papain-digested liver contains almost all the growth stimulating factors of the whole liver; whereas these vary again in fractionated preparations. But as most of the preparations are still obtained either by B. P. method or from Cohn's Fraction G, it is considered to be of interest to study the various amino-acids, present in liver, — raw, proteolysed, Cohn Fraction G, and *Extractum Hepatis Siccum*, B. P. The results of the investigations that have so far been carried out have been embodied in the experimental part of this paper. For simplicity and ready availability beef liver was taken for the above study.

### EXPERIMENTAL

Fresh beef liver was collected from the local slaughter house. A part of it was minced and dried to a constant weight and this was regarded as whole liver in the paper. Raw liver was used for the preparation of proteolysed liver according to Davis *et al.* (*loc. cit.*), Cohn's fraction G (cf. Cohn *et al.*, *J. Biol. Chem.*, 1928, 77, 325), and *Extractum Hepatis Siccum* (B. P. 1932).

The amino-acids as present in all the above liver preparations were determined. The diamino-acids, histidine, arginine and lysine were estimated according to Kossel and Kutscher (*Z. physiol. Chem.*, 1900, 31, 165) and the amino-acids, tryptophane (Horn and Jones, *J. Biol. Chem.*, 1945, 157, 154), methionine (Macarthy and Sullivan, *J. Biol.*

*Chem.*, 1941, 141, 871) and tyrosine (Weiss, *Biochem. Z.*, 1919, 97, 170) were estimated by colorimetric procedure using Klett-Summerson photoelectric colorimeter. The results have been recorded on the basis of the dry powder in Table I.

TABLE I

Preparations.	Dry solid per 100 g. of raw liver.	Total protein on dry basis.	Percentage expressed on total protein.					
			Histidine.	Arginine.	Lysine.	Tyrosine.	Tryptophane.	Methionine
Wole liver	27.5	67.27%	1.89%	5.9%	4.2%	3.3%	0.98%	4.0%
Proteolysed liver	16.7	75.9	2.1	5.6	4.8	3.0	1.2	3.5
Chon's Fraction 'G'	1.24	80.37	1.66	3.85	7.6	1.3	1.08	1.3
<i>Extractum Hepatis Siccum</i>	2.88	46.68	4.6	1.07	10.3	1.1	Trace	3.6

Growth factors of proteolysed liver and fractionated liver preparations were determined by estimating the acid produced by the growth of *Lactobacillus casei* according to the method of Snell and Strong (*Ind. Eng. Chem. Anal. Ed.*, 1939, 11, 346). The results are recorded in Table II.

TABLE II

*Formation of acid from various preparations of liver*

Results expressed as total number of c. c. of 0.1N-acid produced for 10 c. c. basal medium.

Preparations.      Amts. expressed as % raw liver with respective amount of N<sub>2</sub> as mg. per cent.

	1		2		3		4	
	N <sub>2</sub> .	Acid.	N <sub>2</sub> .	Acid.	N <sub>2</sub> .	Acid.	N <sub>2</sub> .	Acid.
Proteolysed liver	11.39	1.6	22.78	2.0	45.56	2.4	91.12	2.8
Aqueous extract of liver	5.37	1.4	10.74	1.60	21.48	1.8	42.96	1.8
Cohn's Fraction 'G'	1.59	0.2	3.18	0.40	6.36	0.6	12.72	0.6

The amount of raw liver in each preparation being the same, percentage of nitrogen and growth factors are highest in the proteolysed liver.

## DISCUSSION

It may be noticed from Table I that the amino-acid contents of the proteolysed liver preparations are almost of the same order as present in the original liver ; whereas

in other preparations their percentages differ appreciably. The tyrosine content of the proteolysed liver is 3.0 % of the total proteinous body, whereas the same in the whole liver is found to be 3.3%. Liver is also a good nutritive substance for the growth of *Lactobacillus casei*. In assaying the different preparations the amount of acid produced in the basal medium by the *Lactobacillus* is found highest where proteolysed liver is used as a nutritive factor (vide Table II). The proteolysed liver is quite effective in small dosage in uncomplicated cases of tropical macrocytic anaemia (cf. Davis *et al.*, *loc. cit.*). The findings in the present investigation tend to indicate that the active physiological principles as present in original liver remain almost unchanged in proteolysed liver preparations, and as such it appears that a proteolysed liver may be a better therapeutic preparation for the treatment of those type of anaemia where liver is indicated (cf. Das-Gupta, Ganguly and Chatterji, *Ind. Med. Gaz.* 1946, 81, 83).

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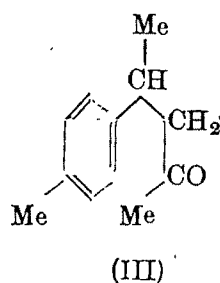
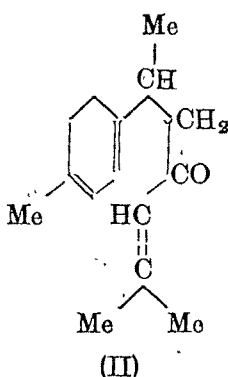
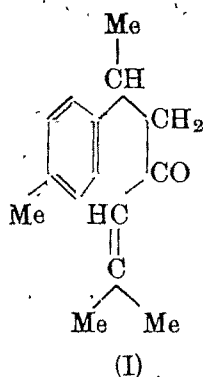
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# STUDIES IN MONOCYCLIC SESQUITERPENES. AN UNAMBIGUOUS SYNTHESIS OF *AR*-TURMERONE

BY SAILENDRA MOHAN MUKHERJEE

*ar*-Turmerone, the aromatic ketone obtained from *Curcuma longa*, has been synthesised by an unambiguous method.

The occurrence in natural oils of sesquiterpenes and their derivatives accompanied by related aromatic derivatives is rather uncommon. It is therefore of particular interest that the elegant investigations of Rupe (Rupe, Clär, Pfau and Plattner, *Helv. Chim. Acta*, 1934, 17, 372) have shown that the oil from the tubers of *Curcuma longa* contains a ketone having aromatic characteristics. The ketone has been named *ar*-Turmerone (I). A sesquiterpene ketone, turmerone, has also been shown to be present in the curcuma oil. It is represented by (II)

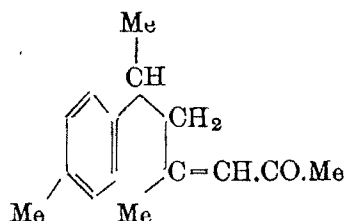


The most important experiment in the elucidation of the constitution of *ar*-turmerone (I) is its treatment with methanolic caustic potash, when acetone and curcumone (III) are obtained. This fission at the double bond on treatment with alkali is characteristic of the  $\alpha\beta$ -unsaturated ketones. Curcumone has been synthesised by Rupe and Wiedner-Kehr (*ibid.*, 1924, 7, 654) by treatment of the acid chloride of  $\beta$ -(*p*-tolyl)-butyric acid with zinc methyl.

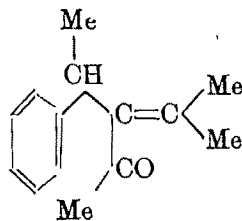
On catalytic hydrogenation in presence of nickel catalyst *ar*-turmerone affords a dihydro derivative, also synthesised by Rupe and Gassmann (*ibid.*, 1936, 19, 569) by three different methods. From the synthetical point of view these syntheses establish the constitution of *ar*-turmerone except the position of the double bond in the side-chain.

Rupe and Gassmann (*loc. cit.*) have also synthesised *ar*-turmerone bycondensing curcumone (III) with acetone in presence of dry sodium

ethoxide. But it will be observed on scrutiny that the above method of synthesis of *ar*-turmerone is capable of giving rise to other compounds having the structures (IV) and (V), so that it is not free from ambiguity.



(IV)

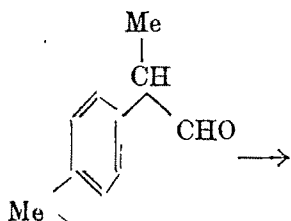


(V)

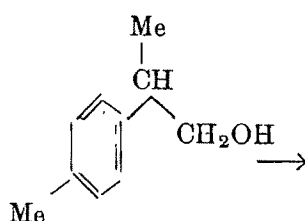
So it was thought desirable to synthesise *ar*-turmerone by a method which might leave no doubt about its constitution.

The present method, described in the following lines, starts from  $\alpha$ -(*p*-tolyl)-propionaldehyde (VI) which, in its turn, is prepared from *p*-tolylmethyl ketone following the procedure of Dutta (*J. Indian Chem. Soc.*, 1941, 18, 233). Reduction of the above aldehyde (VI) was first attempted with sodium and moist ether, but the yield was not satisfactory owing to the appreciable formation of the corresponding pinacol. The alcohol (VII) is then obtained in good yield by reducing the aldehyde (VI) with zinc dust and acetic acid. Conversion of the alcohol (VII) into the corresponding bromide (VIII) is accomplished in the usual way by means of phosphorus tribromide or 48% hydrobromic acid, the latter reagent giving a better yield. The Grignard complex, prepared from the bromide (VIII), on being allowed to react upon the piperidine of  $\beta\beta$ -dimethylacrylic acid according to the condition laid down by Rupe and Gassmann (*loc. cit.*), gives the desired ketone (I).

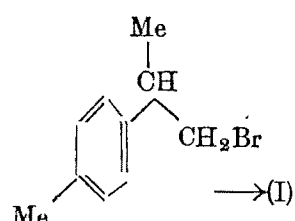
The above Grignard reagent is allowed to react upon  $\beta$ -methylcrotono-nitrile under the conditions of Butenandt and Schmidt-Thomé (*Ber.*, 1938, 71, 1487) when the ketone (I) is obtained in better yield.



(VI)



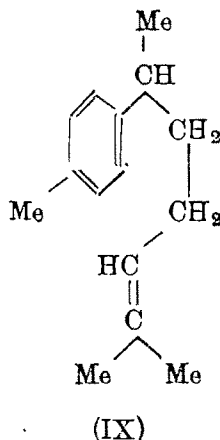
(VII)



(VIII)

In this connection, it is rather interesting to note that the semicarbazone or the hydrazone of *ar*-turmerone (I) on reduction according to Wolff-Kishner

method is expected to give  $\alpha$ -curcumene which has been ascribed the structure (IX) by Simonsen *et al.* (*J. Chem. Soc.*, 1939, 1504 ; 1940, 451) based on analytical as well as synthetical data. The present work may be schematically represented thus :



### E X P E R I M E N T A L

*$\beta$ -(p-Tolyl)-propyl Alcohol (VII).*—Zinc dust (65 g.) in small portions was added during 2 hours to a solution of  $\alpha$ -(p-tolyl)-propionaldehyde (VI, 30 g.) in acetic acid (300 c.c.). Then the whole mixture was heated on the sand-bath for 36 hours. After decanting the liquid from the zinc-sludge most of the acetic acid was nearly neutralised with dilute caustic soda solution so that the mixture remained just acidic. The liquid was then extracted with ether, the ether-extract combined with the ether washings of zinc-sludge, washed with water and then dried ( $\text{Na}_2\text{SO}_4$ ). The residue left after the removal of ether gave on distillation the desired product (27 g.), free from aldehydic smell, b. p.  $102^\circ/5$  mm. (Found : C, 79.82 ; H, 9.26.  $\text{C}_{10}\text{H}_{14}\text{O}$  requires C, 80.0 ; H, 9.33 per cent).

*$\beta$ -(p-Tolyl)-propyl Bromide (VIII).*—A mixture of the above alcohol (27 g.), hydrobromic acid (48%, 60 c.c.) and concentrated sulphuric acid (10 c.c.) was refluxed for 4 hours. The cooled reaction mixture was diluted and the heavy layer extracted with ether, the ethereal layer washed with sodium bicarbonate solution and water and then dried ( $\text{CaCl}_2$ ). After the solvent was driven off, the residue on distillation gave the bromo derivative (VIII) passing over at  $88/6$  mm, yield 32 g. (Found : Br, 37.08.  $\text{C}_{10}\text{H}_{13}\text{Br}$  requires Br, 37.5 per cent).

*ar-Turmerone (I).*—Magnesium (2 g.) was dried in *vacuo* and taken in ether (5 c.c.) and to this was added 0.5 c.c. of methyl iodide to start the reaction. Then the above bromide (VIII, 10 g.) in ether (10 c.c.) was added dropwise during half-an-hour, the flask being heated on the water-bath. After this the mixture was refluxed for further 1 hour to complete the formation of the Grignard complex. To this boiling mixture was then added  $\beta$ -methylecrotononitrile (5 g.), the ether driven off and thiophen-free benzene (10 c.c.) introduced. The refluxing was

continued for 4 hours after which the yellowish ketimino compound was decomposed in the cold with acetic acid and the mixture heated for 15 minutes. Water was then added and heated for further 15 minutes. The cooled mixture was then extracted with ether, the ether-benzene layer washed with sodium bicarbonate solution and water and then dried. After the evaporation of the solvent, the residue was fractionated in vacuum when the desired ketone (I) passed over at  $158^{\circ}/8$  mm. (lit. b. p.  $159-60^{\circ}/10$  mm.). (Found: C, 82.96; H, 9.1.  $C_{15}H_{20}O$  requires C, 83.33; H, 9.26 per cent).

The *semicarbazone*, prepared in the usual way, first separated as a thick heavy oil and then solidified after a very long time (2 months). After crystallisation from dilute alcohol it melts at  $106^{\circ}$  (lit. m. p.  $108-109^{\circ}$ ). (Found: N, 15.26.  $C_{16}H_{23}ON_3$  requires N, 15.38 per cent).

*Piperidide of  $\beta\beta$ -Dimethylacrylic Acid.*— $\beta\beta$ -Dimethylacrylic acid (20 g.) was treated with thionyl chloride (16 c.c.) and the solution kept overnight after which the excess thionyl chloride was driven off by the water pump. The residue was then distilled when the acid chloride of  $\beta\beta$ -dimethylacrylic acid came over at  $118^{\circ}$ , yield 19 g.

The above acid chloride (19 g.) was added with shaking to piperidine (40 g.), well-cooled in ice, when vigorous reaction took place. After standing for half an hour the mixture was diluted with water, extracted with ether, the ethereal extract washed with dilute sulphuric acid, water and then dried. The solvent being removed, the residue was distilled in vacuum when 28 g. of the piperidide, b.p.  $92^{\circ}/10$  mm., were obtained. (Found: N, 8.24.  $C_{10}H_{17}ON$  requires N, 8.38 per cent).

*Grignard Reaction with the Piperidide of  $\beta\beta$ -Dimethylacrylic Acid.*—To the Grignard complex, prepared from 10 g. of the bromide (VIII), 2 g. of Mg and 10 c.c. ether, were added in the cold with shaking 9 g. of the piperidide of  $\beta\beta$ -dimethylacrylic acid. After driving off the ether 10 c.c. of thiophen-free benzene were added and the mixture refluxed for 4 hours. The cold reaction mixture was then decomposed with dilute acetic acid, heated for 15 minutes on the water-bath, then diluted with water and extracted with ether. The ether extract was washed with cold dilute hydrochloric acid, sodium bicarbonate solution, water and then dried. The residue left after the evaporation of the solvent was fractionated in vacuum when the desired ketone (I) was obtained in poor yield and came over at  $156^{\circ}/7$  mm. (Found: C, 82.86; H, 9.21.  $C_{15}H_{20}O$  requires C, 83.33; H, 9.26 per cent).

The author's grateful thanks are due to Prof. P. C. Mitter for his valuable suggestions and encouragement during the course of this investigation.



# PHYSICO-CHEMICAL STUDIES OF COMPLEX FORMATION BETWEEN MOLYBDIC AND TARTARIC ACIDS. PART V. ELECTROMETRIC STUDIES

By A. B. BISWAS

When tartaric acid is added in increasing amounts to a definite quantity of a molybdic acid sol, the rate of change of specific conductivity per mole of  $H_2T$  i.e.  $\frac{d\kappa}{d(H_2T)}$  (where  $\kappa$  is the observed increase in specific conductivity over the sum of the specific conductivities due to the components assuming no reaction), and the corresponding value of  $\frac{d[H^+]}{d(H_2T)}$  reach maximum when the two components are present in equimolecular proportion, and this may be associated with the formation of a complex containing the two components in the same ratio as in the mixture i.e. 1:1. The observed increase of anionic conductivity of the mixtures as above over the sum of the components anionic conductivities, when present separately, is ascribed either to the dissolution of colloidal particles or miscelle ions initially present, or to the formation of a much stronger ionising complex imparting a higher concentration of the complex anions when present separately or more preferably to both of them.

Enhancement of electrolytic conductivity and  $H^+$ -ion concentration of a tartaric acid solution on addition of molybdic acid and the evidences associated with the formation of a complex in solution have been discussed.

When tartaric acid is added to a solution of molybdic acid or sodium molybdate, increased electrical conductivity and hydrogen-ion concentration have been observed besides enhanced optical rotations. Magnanini (1890) first observed such peculiarities with boric and tartaric acids and suggested the formation of a complex. Boeseken and collaborators (*Rec. trav. chim.*, 1921 40, 377) from numerous similar studies attempted to employ the phenomenon to reveal in organic molecules the co-existence of hydroxyl groups in certain proximity and the enhanced activity was ascribed to the existence in solution of an acid stronger than either of the components. Rimbach and Ley (*Z. physikal. Chem.*, 1922, 100, 393) electrometrically determined the  $H^+$ -ion concentration of mixtures of boric or molybdic acid with various hydroxyl containing substances and suggested for various mixtures some probable complex associations. Electrometric measurements have also been employed by Britton and Jackson (*J. Chem. Soc.*, 1934, 1055) to investigate the possible complex formation between molybdic or tungstic acid and tartaric acid.

The enhanced conductivity and increased  $H^+$ -ion concentration cannot always be associated definitely with complex formation because examples are known where the electrolytic activity and solubility of a substance are found to increase in presence of a foreign substance. Boric acid is known to be definitely more soluble in solutions of tartaric acid, glycerine, mannitol, etc. (Burgess and Hunter, *J. Chem. Soc.*, 1929, 2838; Bancroft and David, *J. Phys. Chem.*, 1930, 34, 897). Dumanskii and co-workers (*J. Russ. Phys. Chem. Soc.*, 1928, 60, 229; *Kolloid Z.*, 1928, 44, 273) observed the peptisation of Sn and Ti hydroxides in tartaric acid solution. Lemcke (*J. Russ. Phys. Chem. Soc.*, 1905, 37, 1134; *Z. physikal. Chem.*, 1905, 52, 2179) observed that sodium or potassium chloride was more highly ionised in aqueous solution containing 9.87% glycerine. The activity coefficient of HCl is more in glycerol-water mixture than in pure aqueous solution (Lucasse, *J. Amer. Chem. Soc.*,

1926, 48, 526). Unfortunately we do not as yet know about the mechanism of the electrolytic dissociation to be able to ascribe to it or associate it with any particular property of the solvent, so that the hypothesis of higher dissociation of molybdic acid in tartaric acid solution may be verified.

Although the dissolution of colloidal particles has actually been observed, the idea of greater solubility alone cannot explain and correlate all the observed peculiarities without assuming a complex compound formation.

The object of the present investigation is to study the change in conductivity and  $H^+$ -ion concentration in different mixtures of molybdic acid sol and tartaric acid and to associate the results with the indication of the formation of a complex in molecular ratio of the two components, and to examine whether any evidence of dissolution or breakdown of polymeric anions in molybdic acid sol into simpler ones, can be obtained from electrometric measurement.

## EXPERIMENTAL

The methods of measuring the conductivity and hydrogen-ion concentration are the same as described before (Ghosh and Biswas, *J. Indian Chem. Soc.*, 1945, 22, 279, 295). In Table I are represented the results of change of conductivity of a definite amount of  $MoO_3$  sol, brought about by the addition of gradually increasing amount of *d*-tartaric acid. The corresponding  $p_H$  values of the mixtures are given in Table II.

TABLE I

$[MoO_3]$  = Conc. of  $MoO_3$  in the mixture  $= 253.7 \times 10^{-4}$ .

$[H_2T]$  = Conc. of tartaric acid in the mixture.

$\kappa_{MoO_3}$  = Sp. conductivity of  $MoO_3$  sol when present separately at the same concentration as in the mixture.

$\kappa_{H_2T}$  = Sp conductivity of tartaric acid solution when present separately at the same concentration as in the mixture.

$\frac{d-\kappa}{d(H_2T)}$  = Rate of change of specific conductivity (diff.) per mole of  $H_2T$  of the mixture observed over the sum of the components assuming no reaction.

$[H_2T]$ .	$\kappa_{H_2T}$ .	$\kappa_{MoO_3}$ .	$\kappa_{H_2T}$ .	$\kappa_{Obs}$	Diff.	$\frac{d-\kappa}{d(H_2T)}$
$63.43 \times 10^{-4}$	$7.60 \times 10^{-4}$	$20.38 \times 10^{-4}$	$27.98 \times 10^{-4}$	$33.08 \times 10^{-4}$	$5.05 \times 10^{-4}$	$796.2 \times 10^{-4}$
126.8	11.84		32.22	44.54	12.32	994.5
190.3	15.64		34.92	56.47	21.55	1132.0
253.7	17.20		37.58	67.83	40.25	1588.0
507.5	24.00		44.98	103.60	58.62	1155.0
761.2	29.46		49.84	123.70	73.86	970.5
1015.0	35.40		55.78	135.5	79.72	785.6
1268.0	40.04		60.48	141.7	81.22	640.7
1522.0	43.35		63.78	145.9	82.17	539.9

TABLE II

$p_H(\text{mix})$  = obs.  $p_H$  values of the mixture of  $\text{MoO}_3$  sol and tartaric acid.

$p_H(\text{MoO}_3)$  = obs.  $p_H$  values of  $\text{MoO}_3$  sol when present separately at the same concentration as in the mixture = 2.618.

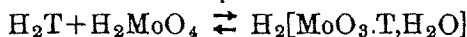
$p_H(\text{H}_2\text{T})$  = obs.  $p_H$  values of  $\text{H}_2\text{T}$  solution when present separately at the same conc. as in the mixture.

$\frac{d[\text{H}^+]}{d(\text{H}_2\text{T})}$  = rate of change of  $[\text{H}^+]$  (diff.) per mole of  $\text{H}_2\text{T}$  added, of the mixture observed over the sum of the components assuming no reaction.

$p_H(\text{H}_2\text{T})$	$p_H \text{ mix.}$	$[\text{H}^+] \text{ MoO}_3$	$[\text{H}^+] \text{ H}_2\text{T}$	$[\text{H}^+] \text{ MoO}_3$	$[\text{H}^+]_{\text{obs.}}$	Diff.	$\frac{d[\text{H}^+]}{d(\text{H}_2\text{T})}$
$[\text{H}^+]_{\text{H}_2\text{T}}$							
2.860	2.402	$0.2410 \times 10^{-2}$	$0.2183 \times 10^{-2}$	$0.4598 \times 10^{-2}$	0.8963	-0.636	-1.001
2.490	2.164	..	.3236	.5646	0.6852	0.1208	0.9608
2.421	1.912	..	.3802	.6212	1.225	0.6038	3.178
2.370	1.790	..	.4266	.6676	1.622	0.4544	3.761
2.285	1.681	..	.5188	.7598	2.340	1.6702	8.293
2.208	1.465	..	.6177	.8687	3.428	2.5693	2.581
2.180	1.443	..	.6597	.9007	3.614	2.7138	2.189
2.150	1.429	..	.7023	.9433	3.724	2.709	1.833

## DISCUSSION

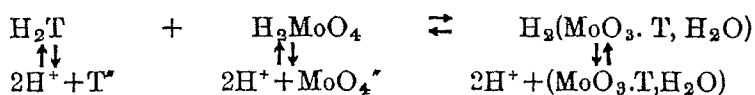
We have already shown (Biswas, *J. Indian Chem. Soc.*, 1945, 22, 351) that tartaric and molybdic acids form a complex as follows :



It will be seen in Tables I and II that when we have started with two solutions at different concentration and adjusted the molecular ratio of the two in different mixtures, the value of  $\frac{d[\text{H}^+]}{d(\text{H}_2\text{T})}$  and  $\frac{d\kappa}{d(\text{H}_2\text{T})}$  reach maximum when the two components are present in the equimolecular ratio. This maxima may be associated with the formation of a complex composed of solute molecules in the same ratios as that existing in the solution i. e. 1 : 1. The detailed systematic investigation in this connection is being dealt with in a subsequent paper.

Apart from ultramicroscopic observations, as was done previously (Biswas, *J. Indian Chem. Soc.*, 1946, 23, 257) that tartaric acid causes dissolution of the colloidal particles or miscelle ions along with the formation of a complex in true solution can be shown thus :

Let us represent the complex formation in the ionic form as follows :



The anionic activity of the mixture of molybdic and tartaric acid solution should decrease considerably due to the formation of one slower moving complex anion at the expense of two faster moving anions. The anionic activity of the

complex solution or of its components, when present separately, can be determined by subtracting the conductivity contributed by the positive ions (i. e.  $H^+$  ions) from the observed total conductivities. From some of the measured data, similar to those in Tables I and II, we have drawn up Table III below, where the calculated sum of the anionic specific conductivity of the two components assuming no reaction, are compared with the values actually observed in the mixture.

TABLE III

$\kappa_a(MoO_3)$  = obs anionic specific conductivity of  $MoO_3$  sol when present separately.

$\kappa_a(T)$  = obs. anionic specific conductivity of tartaric acid solution when present separately.

$\kappa_{a(obs.)}$  = obs. anionic specific conductivity in a mixture of the above two.

$\kappa_a(MoO_3)$	$\kappa_a(T)$	$\kappa_a(MoO_3) + \kappa_a(T)$	$\kappa_a(Obs.)$
$0.57 \times 10^{-4}$	$0.60 \times 10^{-4}$	$1.17 \times 10^{-4}$	$2.45 \times 10^{-4}$
2.76	"	3.36	7.30
12.26	"	12.86	15.94
18.86	"	14.46	17.26
12.02	0.14	12.16	19.16

Contrary to expectation it will be noticed that the observed anionic specific conductivities of the mixtures are appreciably more than the calculated sum assuming that there is no reaction. This phenomenon can be ascribed to either of the two following transformations or more preferably to both of them :

(1) The presence of tartaric acid may cause the dissolution of colloidal particles or miscelle ions when larger number of comparatively mobile small aggregates or simpler ions will be formed to increase the observed anionic conductivity in the mixtures.

(2) As we have assumed the formation of a stronger ionising complex than either of the components, and as the observed hydrogen-ion concentration in the mixture is more than the sum of the hydrogen-ion concentrations in their component solutions, correspondingly the concentration of the complex anion will also be more to cause the observed anionic conductivity to be more than the sum of the two components.

The author's best thanks are due to Sir J. C. Ghosh for his kind interest in this work.

## STUDIES ON THE COMPOSITION OF PEPTONES. PART V.

BY SUDHINDRA NATH SEN

Peptones and protein hydrolysates have been fractionated by dialysis and average peptidal aggregates in these fractions have been determined. The size of these aggregates increases when glucose is added to the peptide solution at an alkaline pH.

The development of protein hydrolysates and amino-acids mixture, suitable for clinical use, has been one of the most important advances in medicine in the past few years. Recently the efficacy of an enzymatic hydrolysate of veal in quickly restoring serum protein after blood depletion in immunised horses has been reported from this laboratory (Basu and Sen, *J. Hyg.*, 1947, 45, 56). Such a treatment of horses before and after bleeding during the process of immunisation may prove significant, specially in the light of the observations of Wissler *et al.* (*J. Immunol.*, 1943, 47, 133; 1946, 52, 267) that the antibody production has a close relationship with serum protein.

A review of current literatures on the use of protein hydrolysate shows that different workers have obtained clinical improvements with products in which proteins have been hydrolysed to various degrees. A desired specification of such hydrolysate has also been recently recorded from this laboratory (Basu, Sen and Bose, *Pharm. J.*, December 28, 1946). But upto now, no definite knowledge exists as to what extent proteins should be hydrolysed so as to give maximum efficiency. So long as the hydrolysate does not contain a true protein, no danger is likely to arise by its parenteral use provided that the peptides, which often cause reaction, are not too large. Completely breaking the protein into its constituent amino-acids also appears to be unnecessary as no proof has ever been given that all proteins in alimentary tract are hydrolysed to biuret-free product before absorption (Van Slyke, *Science*, 1942, 95, 259). It is therefore probable that presence of certain aggregates or polypeptides in the protein hydrolysates is advantageous as it will save time and energy in preparing the first building stone in the formation of blood and tissue proteins (cf. Madden and Wipple, *Physiol. Rev.*, 1940, 20, 194; Fischer, *Naturwiss.*, 1942, 30, 665).

The usual method of determining the number of peptide linkages, and consequently the size of the peptidal aggregates in a sample of peptone or a protein hydrolysate, by estimating the increase in carboxyl or amino groups after complete hydrolysis by mineral acids, gives results which are far from the true picture owing to the product being a mixture of higher and lower peptides. Moreover, as the addition of glucose is an essential requirement in the use of protein hydrolysate in parenteral therapy and as glucose is known to combine with amino-acids and peptides at alkaline or neutral reaction, its addition would therefore increase the size of the peptides in the hydrolysate. Ambler (*Ind. Eng. Chem.*, 1929, 21, 47) has shown that compounds of progressive complexity are formed in glucose-protein reaction depending on the conditions of experiments and as high as 10 moles of glucose may

combine per mole of amino-acid. Compounds with hexose components, joined through N instead of O, have been obtained by Brigl and Keppler (*Z. physiol. Chem.*, 1929, 180, 38). Enders (*Biochem. Z.*, 1943, 313, 352) obtained products from methylglyoxal and glycine in such complex forms that they could not be dialysed. All these show the possibility of increase in the peptidal size of the aggregates when glucose is added to a peptone solution thereby altering the nature of the initial product.

Hence in any work involving comparative studies with peptides, hydrolysed to different stages, it is necessary to find out a method by which these products could be separated and classified into fractions consisting of peptides of comparatively known size. It is also thought desirable to determine to what extent glucose increases the size of the lower peptides so as to influence the original nature of the hydrolysate. A study in these two directions was accordingly undertaken.

Any protein hydrolysate can be separated into different fractions by salt precipitation, but even then it is practically impossible to determine the peptidal aggregates in the lower fractions owing to the high salt concentration. The other alternative method for determining the lower peptides is initial dialysis of the hydrolysate and subsequent estimation of peptide linkage in the dialysate. If the maximum size of the peptidal aggregate that is dialysable through cellophane paper of standardised porosity could be determined, this would for all practical purposes set a limit to the dialysable and non-dialysable fractions. MaBain and Stuewer (*J. Phys. Chem.*, 1936, 40, 1157) have shown that cellophane paper when treated with  $\text{ZnCl}_2$  solution (64%) acquires pores of definite size which are not altered on washing away the  $\text{ZnCl}_2$  solution. In all experiments recorded below,  $\text{ZnCl}_2$ -treated cellophane paper (No. 300) has been used.

## EXPERIMENTAL

The hydrolysate or peptone solution for analysis was diluted so as to contain about 0.8% nitrogen (equivalent to about 5.0% protein). 5 C. c. of this solution were placed in a cellophane bag and dialysed against 40 c. c. of distilled water at 3° to 5°. After 24 hours the dialysate was collected in a flask and the test solution was again similarly dialysed for 24 hours more. Addition of preservative was not found necessary. Dialysis was generally complete after this period as judged by the nitrogen estimation of the dialysate. All the dialysates were mixed together. Initial carboxyl groups in the sample were determined by titrating 2 c. c. of the solution separately in 96% and 50% alcohol using in each case KOH solution of the same alcoholic strength. Difference between the two values gives the carboxyl groups in the peptides (Willstätter *et al.*, *Ber.*, 1921, 54B, 2988). 10 C. c. of the solution were then mixed with 10 c. c. of 6N-HCl and hydrolysed under reflux for 6 hours at 125° (Sen, *J. Indian Chem. Soc.*, 1946, 23, 283). In a peptide ( $\text{R}_1\text{CONHR}_2\text{CONHR}_3\text{COOH}$ ) the increase in carboxyl groups on complete hydrolysis for each COOH group, initially present, gives the number of CONH-linkages.

in the sample. Increase in carboxyl groups for initial acidity, equivalent to each c. c. of 0.1 *N*-KOH, gives the number of peptide linkages per molecular aggregate. Of course in solution, which contains peptides of different sizes, the results give an average figure. Similar experiments with the whole product and with the non-dialysable portions were also carried out. Results are recorded in Table I.

TABLE I

Protein hydro- lysed products.	Whole.		Dialysable portion.		Non-dialysable portion.	
	†Initial COOH	No. of CONH- linkages.*	†Initial COOH.	No of CONH- linkages*	†Initial COOH	No. of CONH- linkages*
Bacto peptone :	(a) 1.21	4.2	(a) 0.60	2.3	(a) 0.21	4.7
dialysable N,	(b) 1.84	4.8	(b) 1.12	2.2	(b) 0.27	4.5
68.2% ; non-	(c) 1.50	4.0	(c) 1.54	2.2	(c) 0.84	4.5
dialysable N,	(d) 1.82	4.0	(d) 2.00	2.2	(d) 0.40	4.7
36.8%..	(e) 1.94	4.2	(e) 2.70	2.4	(e) 0.47	4.7
	Av. 4.2		Av. 2.2		Av. 4.6	
Wittes peptone :	(a) 1.13	4.9	(a) 0.56	3.9	(a) 0.10	6.0
dialysable N,	(b) 1.62	4.9	(b) 0.72	3.8	(b) 0.42	6.0
59.4% ; non-	(c) 2.23	4.7	(c) 1.13	4.0	(c) 0.77	5.7
dialysable N,	(d) 2.80	5.0	(d) 2.20	3.9	(d) 1.15	6.1
40.6%.	(e) 3.01	4.9	(e) 2.51	3.9	(e) 1.70	6.0]
	Av. 4.9		Av. 3.9		Av. 6.0.	
Protein hydro-	(a) 0.60	1.4				
lysate ; dialy-	(b) 1.13	1.5				
sable N, 98.99%.	(c) 1.76	1.2				
	(d) 2.11	1.2				
	(e) 2.50	1.3				
	Av 1.3					

In order to find out whether glucose under the conditons of preparing protein hydrolysate for parenteral use (Basu and Sen, *loc. cit.*, 1947) increases the size of the peptidal aggregates, dialysed portions of each peptone and protein hydrolysates were adjusted to  $pH$  7.8 and 5% glucose solution was added to above and then autoclaved at 15 lbs. for 25 minutes. 2 C. c. of each solution were dialysed in cellophane bags and nitrogen in different portions was determined. Since

†Initial COOH was calculated in equivalent to c.c. of 0.1*N*-KOH in 2 c.c. of the solution after deducting the free amino-acids.

\* per average aggregate.

formaldehyde also reacts with amino-acids and peptides and increases their size (cf. Fraenkel-Conrat and Olcott, *J. Amer. Chem. Soc.*, 1946, **68**, 34) it was thought desirable to compare the effect of this reagent and of glucose on peptone dialysates side by side. The reactions of HCHO with the dialysates were carried out according to Fraenkel-Conrat *et al.* (*J. Amer. Chem. Soc.*, 1945, **67**, 950). To 8 c.c. of the dialysate 1 c.c. of 3.4*M*-phosphate buffer ( $p_H$  8.2) and 1 c.c. of HCHO (37-38%) were added and the solution was placed at 70° for 4 days. The extent of reactions both with glucose and formaldehyde could be judged from the decrease in the Van Slykes amino-nitrogen from the initial value. Results are recorded in Table II.

TABLE II

Dialysates.	Av. No. of peptides linkages.	Total %N.	Van Slyke's $NH_2$ -N%			Dialysable N (as% of total N) with glucose. HCHO.	
			Initial.	Final with glucose.	HOHO.		
Bacto peptone	2.3	(a) 0.280	0.109	0.094	Nil	58.5	50.5
		(b) 0.360	0.140	0.122	..	55.5	52.1
		(c) 0.507	0.207	0.188	..	56.0	51.7
Wittes peptone	3.9	(a) 0.184	0.056	0.041	Nil	51.6	76.0
		(b) 0.300	0.110	0.081	..	55.2	70.2
		(c) 0.456	0.158	0.117	..	54.8	73.1
Protein hydrolysate	1.5	(a) 0.30	0.17	0.14	Nil	87.1	80.7
		(b) 0.37	0.20	0.16	..	87.7	82.0
		(c) 0.45	0.25	0.20	..	86.2	80.3

## DISCUSSION

From the results so far obtained with products containing peptides of different lengths, it appears that on the average peptidal aggregates of five amino-acids residue ( $\approx 4$  peptide linkages) or less are dialysable through cellophane paper No. 300 ( $ZnCl_2$  treated). For all practical purposes, this aggregate of five amino-acids residues may be taken under conditions of experiments as the maximum size of the peptides that are dialysable through cellophane paper. The size of any peptide, of course, depends on the molecular weights of the amino-acids which go to form the aggregate. The arrangements of the amino-acid residues in the main chain do not



vary in different peptides, but the residual weights of different amino-acids which reside in the side chain are variable. If the space occupied by these residues in the side chain is greater than the space occupied by the main chain, the determination of the number of CONH will be of little significance in evaluating the size of the peptides. But as the distance between two -CONH- linkages is near about  $7.0\text{\AA}$  (Astbury and Marwick, *Nature*, 1932, 130, 309) and as in no case the residues in the side chain extend beyond  $11.0\text{\AA}$  from the main chain- (Astbury, *Cold Spring Harbor Symp. Quant. Biol.*, 1934, 2, 15; *Kolloid Z.*, 1934, 69, 340) the length of the main chain in a peptide containing four -CONH- linkages will always be greater than the side chain spacing and this will be the main factor in determining the size of such aggregates. In a lower peptide, however, the side chain spacing may prove significant.

Oxidised glutathione may be taken for all practical purposes to represent a peptide of four -CONH- linkages. To test further the validity of the above experiments glutathione was oxidised by  $\text{CuCl}_2$  according to the method of Lyman and Barron (*J. Biol. Chem.*, 1937, 121, 275) and it was found to be 100% dialysable through cellophane paper. For want of pure higher peptide, non-dialysability of these products could not be tested.

The nature of aggregate formation after reaction with glucose, as judged by decrease in dialysable N and Van Slyke's  $\text{NH}_2\text{-N}$ , are quite different in each case. In glucose-protein reactions reduction in amino-N, as observed by the methods of Van Slyke and Sorensen, has been observed by various workers suggesting  $\text{NH}_2$  groups being involved in the reaction (Kostychev and Brilliant, *Z. physiol. Chem.*, 1923, 127, 224; Borsook and Wasteneys, *Biochem. J.*, 1925, 19, 1126; Fraenkel and Katchalsky, *ibid.*, 1937, 31, 1595; Ågren, *Acta Soc. Physiol. Scand.*, 1940, 1, 105). If the amino groups are the only determining factors, the discrepancies in the results depending on the decrease in amino-N and dialysable N, observed with different hydrolysates could not be explained. Hence the huge increase in molecular size after reaction with glucose, must be sought of in some other type of reaction. It is, however, clear that the effect of either glucose or H.CHO in increasing the molecular size of the aggregate does not primarily depend on the initial size. Some form of group specificity in these types of reactions is apparent. H.CHO is known to react with amide, thiol, guanidyl and possibly with other polar groups in addition to  $\text{NH}_2$  groups (Fraenkel-Conrat *et al.*, *loc. cit.*). Hence it is possible that glucose can also react with groups other than  $\text{NH}_2$  group. Ågren (*loc. cit.*) and Schubert (*J. Biol. Chem.*, 1939, 130, 601) have shown that glucose reacts with -SH group of cysteine. Since the bond energy of co-valent hydrogen linkage of -SH and -NH are nearly equal, i.e. about 87 K/cal (Pauling "The Nature of Chemical Bonds", Cornell University Press, 1944) possibility of combination of glucose with -NH groups also exists. In either case, aggregate formation will be independent of the amino-nitrogen. Increase in molecular size due to aggregate formation with H.CHO is not so great as that with glucose and this is due to the higher molecular weight of glucose in comparison with H.CHO. As the initial size of the peptides does not always count in the

formation of aggregates with glucose, the final product after the addition of glucose in any protein hydrolysate, used for parenteral therapy, should also be standardised with respect to the non dialysable N.

### C O N C L U S I O N S

Determination of peptidal aggregate in any protein degraded product, by estimating the increase of COOH groups on complete hydrolysis, gives a result which is far from the true picture owing to the product being a mixture of higher and lower peptides. Initial fractionation of the protein hydrolysed products can be effected by dialysis through cellophane paper which has been previously treated with  $ZnCl_2$  solution so as to have pores of definite size. Maximum peptidal size, dialysable through such cellophane paper, has been found to be, on average, aggregates of five amino-acids. Awaiting further researches on the choice of membranes which will allow the separation of peptides on a more definite basis, the results embodied in the paper tentatively suggest a method by which the separation of peptides can be effected on a more definite basis than previously employed.

Addition of glucose and formaldehyde to peptone solution at alkaline reaction and subsequent autoclaving increase the size of peptides. This increase in the size of the aggregates has no close relation with the initial size of the peptides. Certain specific groups, besides amino groups, have been suggested to take part in glucose-peptone reaction.

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# ON THE POSSIBLE RELATIONSHIP BETWEEN CAROTENE, VITAMIN-C, TOTAL ACIDITY, $p_H$ AND SUGAR CONTENT OF DIFFERENT VARIETIES OF MANGOES DURING THEIR GREEN AND RIPE CONDITIONS

By N. M. BASU, G. K. RAY AND N. K. DE

Several varieties of mangoes have been examined in their unripe, partly ripe and fully ripe conditions for their carotene, vitamin-C and sugar content and for their total acidity and  $p_H$  values.

This investigation was undertaken with a view to finding out (i) the nutritive values of different varieties of mangoes (available in Calcutta) with regard to their carotene, vitamin-C, and sugar content, and their total acidity and  $p_H$ , (ii) variations in these values during their green and ripe conditions, and (iii) whether any relationship exists between (a) the progressive diminution of vitamin-C and of total acidity or the gradual rise in  $p_H$ , or (b) between the increase in carotene and that of sugar, and (c) between the decrease of vitamin-C or of total acidity on the one hand and the increase of carotene or sugar on the other. To carry out this investigation properly in the case of each variety of mango, it is necessary to get hold of green mangoes of a particular variety from the same tree,\* to analyse some of them for these constituents, to ripen others in the laboratory in a thermostat and to analyse these ripe mangoes again for the same constituents. As it was not possible to know whether mangoes of a particular variety, packed up in a basket, belonged to the same tree or not, care was taken to select green and ripe mangoes which appeared to be of the same general appearance from the same basket. These were then analysed. In some cases green mangoes were ripened in the laboratory and then analysed.

## EXPERIMENTAL

*Estimation of Total Acidity,  $p_H$ , and Sugar.*—A weighed amount of the pulp of the mango under examination was triturated with sand and distilled water and the extract so obtained was decanted off into a 250 c.c. measuring flask. This process was repeated till complete extraction. The total extracts were collected in the flask and made up to a known volume with distilled water.

Aliquot portions of this liquid were used for the determination of sugar by the micro-Benedict method, of  $p_H$  with the Coles' potentiometer, while the remaining portion was titrated directly with a  $N/10$   $Na_2CO_3$  solution for total acidity.

*Estimation of Vitamin-C.*—Vitamin-C was extracted from a weighed amount of the sample by thoroughly macerating with a mixture of  $HCl$  (4%) and metaphosphoric acid (2%) and sand. It was then estimated as usual by titration of the extract with Tillman's dye before and after its aliquot portions were treated with hex-oxidase (ascorbic acid oxidase), prepared from drumstick juice (Srinivasan, *Biochem. J.*, 1937, 31, 154).

\* It is well known that mangoes of the same denomination differ widely in taste and therefore in chemical composition not only when they belong to different places but also amongst different gardens of the same locality.

*Estimation of Carotene.*—The weighed sample of the mango pulp was thoroughly ground with glass powder and extracted with absolute alcohol several times and the extract was then kept in a stoppered cylinder or preferably in a separating funnel. The pulp was then extracted with petroleum ether for 4 to 5 times till the pulp was colourless. Both the alcoholic and ethereal extracts were

TABLE I

No. of samples.	Variety of mango.	*Carotene (I. U.)	†Vitamin-C.	Total acidity‡	pH.	Sugar**
<i>Langra</i>						
1.	(unripe)	11.6	220.4	19.0 c.c.	4.2	2.2
2.	(another sample)			42.0	3.11	1.15
3.	(partly ripe)	18.8	120.0	17.0	4.2	1.34
4.	(ripe)	60.0	60.0	7.25	5.19	2.0
<i>Fazli</i>						
1.	(partly ripe)	9.5	24.0	13.0	4.13	1.68
2.	(ripe)	45.2	20.8	8.25	4.33	2.5
3.	(Benares variety, unripe)	4.0	17.6	20.0	3.76	2.6
4.	.. (ripe)	31.5	12.8	10.0	4.36	3.7
<i>Totafully</i>						
1.	(partly ripe)	16.0	24.0	23.0	3.57	2.5
2.	(ripe)	24.6	16.0	13.0	4.1	4.0
<i>Bombai</i>						
1.	(partly ripe)	16.4	18.0	11.5	4.0	3.0
2.	(ripe)	54.4	6.4	8.0	4.63	3.39
<i>Kishanvog</i>						
1.	(green)	7.2	28.8	20.0	3.8	2.56
2.	(ripe)	42.4	17.5	6.5	4.63	3.12
<i>Taraiha</i>						
1.	(unripe)	2.8	36.0	24.24	3.29	2.22
2.	(ripe)	14.8	22.0	10.5	4.33	2.5
<i>Sepia</i>						
1.	(unripe)	6.5	14.4	22.5	3.73	2.8
2.	(partly ripe)	11.5	12.0	31.5	3.66	2.8
3.	(ripe)	25.5	9.6	23.0	4.06	3.9
4.	(ripe)	45.0	9.6	18.5	4.1	4.2

mixed up in the separating funnel (graduated) and then allowed to separate, and a measured volume of water was added to make the alcoholic layer about 85%. The mixture was then thoroughly shaken in the separating funnel and the alcoholic layer was thrown out after again allowing the two layers to separate. The petroleum

\* The carotene figures (per 100 g. of mango pulp) are expressed as microgrammes of mixed carotene.

1 microgramme is considered to represent roughly 1 International unit (I. U.) of vitamin-A.

† Expressed in mg. per 100 g. pulp.

‡ per 100 g. pulp equivalent to *N*-acid.

\*\* Expressed as g. per 100 g. of pulp.

ether layer containing the carotene was washed successively with 85% and 70% alcohol and repeatedly with water. The moisture in the ethereal layer was then removed by anhydrous  $\text{Na}_2\text{SO}_4$  and shaken with sufficient powdered dry  $\text{CaCO}_3$  to remove chlorophylls and possible traces of non-hydrocarbon pigments. The ethereal solution was next filtered and the filtrate was made up to a suitable volume. The carotene content of the extract was estimated colorimetrically by matching against a standard solution of pure  $\beta$ -carotene.

The results of analysis of several samples of mangoes are given in Table I.

### CONCLUSIONS

On examining these results of analysis the following conclusions are drawn :

(a) The unripe mangoes are, as was expected, more acid and richer in vitamin-C than ripe mangoes.

(c) Ripe mangoes are richer in carotene and sugar than unripe ones.

(c) The increase in carotene content of mangoes on ripening is generally proportionately much greater than the decrease in their vitamin-C or acid content and bears no relation to the sugar content of these mangoes. (In the case of Totafully and Bombai, the increase in carotene is closely similar to the decrease in vitamin-C on ripening).

(d) No proportional relationship exists between the vitamin-C content of a mango and its acidity or between the decrease of acidity and the increase of sugar content of a mango on ripening.

(e) With the same or nearly the same  $p_H$ , different acid contents are found in different mangoes and also no proportional relationship exists in many cases between its acid content and  $p_H$ , indicating that the organic acid salt content of these mangoes varies widely, i.e., their potentially acid or basic character is different with different mangoes.

(f) Ripe *Langras* are richer in both carotene and vitamin-C than other mangoes.

(g) The ripe *Bombai* mangoes, *Fazli*, *Sepia* and *Kishenvog* are also fairly rich in carotene.

(h) The vitamin-C content of unripe *langras* is much greater than that of other mangoes.

(i) The sugar content of ripe *Sepia*, *Totafully* and *Bombai* is appreciably higher than that of other mangoes,

(j) The acid content of ripe *Kishenvog* is the least and that of ripe *Langra*, *Bombai*, *Fazli* and *Taraiha* is also quite small in comparison with other mangoes.

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## ON THE VITAMIN-C AND CAROTENE CONTENT OF SEVERAL HERBS AND FLOWERS USED IN AYURVEDIC SYSTEM OF MEDICINE

BY N. M. BASU, G. K. RAY AND N. K. DE

Of the various herbs etc. examined, mature "Neem" leaves are very rich, tender Neem leaves, Vasak, Dhania and Babla thorn leaves are quite rich, both in carotene and vitamin-C and Pudina, Kukshima, Amrul, Durba grass, Gandal leaves are quite rich in carotene only. The vitamin-C content of Nishinda, Shiuli, Visalya-karani and Kukshima leaves, increases very greatly after frying in oil.

This investigation was undertaken with a view to throwing light on the possible relationship between the medicinal properties of these herbs etc, and their vitamin-C and carotené contents.

Vitamin-C and carotene were extracted and estimated in the same way as was done in the case of mangoes (Basu, Ray and De, *this Journal*, 1947, 24, 355). As in the course of preparation of medicines from these herbs, some of them are fried in oil and subjected to other forms of heat treatment, the alteration in the vitamin-C content of some of them after heat treatment has been noted. The results of estimation are given in the accompanying table.

It is curious that mature *neem* leaves, which are used extensively in the preparation of medicines for the healing of obstinate sores, are very rich in both vitamin-C and carotene, but tender leaves, which are taken either in soup or after frying, contain much less vitamin-C and carotene. *Vasak* leaves and their extract are said to be efficacious in cough and cold. They are also rich in both vitamin-C and carotene. *Dhania* (coriander) leaves are widely taken in Bengal. They are found to be rich both in vitamin-C and carotene and their use should be encouraged. *Babla* thorn leaves are not consumed but are used for poultice over abscesses. They are rich both in vitamin-C and carotene. If the vitamin-C or carotene content or both of these leaves were an index of their sore-healing properties, then all those leaves, which are rich in both, should be experimented upon for this purpose, *Pudina* leaves, which are eaten raw, are quite rich in carotene, but not in vitamin-C. The leaves which are rich in carotene are *Neem*, *Pudina*, *Dhania*, *Babla*, *Kukshima*, *Amrul*, *Gandal* etc. Remembering that the optimal daily requirements of vitamin-C and vitamin-A or carotene are 60 mg. and 4000 I. U. or  $\gamma$  (micro-gramme), one can easily find out from the list appended (Table I) how much of these vitamins he can get from these articles when consumed.

A noteworthy feature of some of these herbs, particularly *Nishinda*, *Shiuli*, *Visalya-karani* and *Kukshima*, is that the vitamin-C content instead of being decreased by frying in oil, increases considerably. The percentage increase or decrease of vitamin-C after heat treatment has been shown in the table. Increase in vitamin-C content on heat treatment in vegetables has been previously shown by various workers in India and abroad and Dr. B. C. Guha has given the name of ascorbigen to the substance which is converted into vitamin-C on heating.

TABLE I

No.	Name of samples.	Bot. names.	*Free vitamin-C (mg. per 100 g.)	% Increase or decrease after the heat treatment.	Carotene in $\gamma$ per 100 g.
1.	Neem leaves (mature)	<i>Melia azadiracta</i>	500.0		7500.0
	Do .. (tender)		300.0		8400.0 1250.0
2.	Vasak leaves (mature)	<i>Adhatoda vasica</i>	250.0		4500.0
	Do (another sample)		186.0 (89.0)	46.0 (decrease)	
3.	Dhania leaves	<i>Coriandrum sativum</i>	250.0		5200.0
	Do (another sample)		88.0 (83.0)	Nil	
4.	Babla kanta (leaves)	<i>Acacia arabica</i>	200.0		4800.0
5.	Nishinda leaves	<i>Vitex negundo</i>	150.0		3500.0
	Do (another variety)		60.0 (120.0)	100.0 (increase)	
6.	Durba grass	<i>Cynodere dactylon</i>	150.0		4600.0
7.	Marigold flower	<i>Tagetes patula</i>	135.0		
	Do (another variety)		25.0		
8.	Marigold leaves		130.0		
9.	Shiuli leaves	<i>Nyctanthes arbortristis</i>	130.0		2000.0
	Do (another sample)		30.0 (60.0)	100.0 (increase)	
10.	Amrul sak	<i>Oxalis corniculata</i>	125.0		3600.0
11.	Amra	<i>Spondias mangifera</i>	100.0		
12.	Bel leaves	<i>Aegle marmelos</i>	100.0		4500.0
13.	Gandal leaves	<i>Paideria foetida</i>	100.0 (110.0)		
	Do (another sample)		25.0	10.0 (increase)	3600.0
14.	Tulsi leaves	<i>Ocimum sanctum</i>	83.0		2500.0
15.	Pathar kuchi leaves	<i>Bryophyllum calycium</i>	73.0 (43.0)		
	.. (another sample)		40.0	40.0 (decrease)	1800.0
16.	Kantakari	<i>Solanum feroc</i>	70.0		1800.0
17.	Bitter gourd (small) leaves	<i>Momordica charantia</i>	50.5 (50.0)	Practically nil	
	.. (another sample)		40.0		2400.0

TABLE I (contd.)

No.	Name of samples.	Bot. names.	*Free vitamin-O (mg. per 100 g.)	% Increase or decrease after the heat treatment.	Carotene in $\gamma$ per 100 g.
18.	Arhar leaves	<i>Cajanus indica</i>	50.0		3100.0
19.	Haritaki	<i>Terminalia chebula</i>	50.0		Nil
20.	Kalmegh	<i>Andrographis paniculata</i>	50.0 (60.0)	20.0 (increase)	
	Do (another sample)		Traces		3400.0
21.	Hincha leaves	<i>Echydra fluchians</i>	50.0		300.0
22.	Thalkuni leaves	<i>Hydrocotyl Japonica</i> or	40.0 (96.0)	10.0 (decrease)	
	Do (another sample)	Do <i>Asiatica</i>	20.0		2400.0
23.	Gulancha stick	<i>Teriospora cordifolia</i>	40.0		160.0
24.	Kakmachi leaves	<i>Solanum nigrum</i>	40.0 (40.0)	Nil	
	Do (another sample)		20.0		2800.0
	Do seeds		20.0		240.0
25.	Punarnabá	<i>Boerhaavia rarpous</i>	39.0 (30.0)	23.0 (decrease)	
26.	Kukshima leaves	<i>Blumen lacera</i>	30.0 (50.0)	66.6 (increase)	
	Do (another sample)		Nil		4000.0
27.	Onion stalk	<i>Allium cepa</i>	30.0		260.0
28.	Kulatha Kanta (leaves)	—	30.0		2600.0
29.	Visalyakarani	<i>Eupatorium ayapana</i>	35.0 (50.0)	100.0 (increase)	2200.0
30.	Ohálta	<i>Dellenia indica</i>	20.0		Traces
31.	Ghreetakumari	<i>Aloe perfoliata</i>	20.0		600.0
32.	Gok-khur seeds	<i>Tribulus cistoides</i>			
33.	Pudina	<i>Mentha sativa</i>	16.0		5400.0
34.	Shetpunni	<i>Trianthema monogynum</i>	15.0		2300.0
35.	Simul mul	<i>Bombax malabocicum</i>	Traces		Nil
36.	Aswagandha	<i>Withania somnifera</i>	Traces		
37.	Khet-pabra	<i>Mollugo stricta</i>	Traces		8600.0
38.	Jonki leaves		Traces		1800.0
39.	Pora mula		Traces		
40.	Dhutra leaves	<i>Datura stramonium</i> or <i>D. fastuosa</i>	Traces		3500.0
41.	Bahera	<i>Terminalia belerica</i>			Nil
42.	Figs	<i>Ficus histida</i>			Traces
43.	Satamul	<i>Asparagus racemosus</i>	Nil		Nil

\* Figures in parentheses refer to those after frying.

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## PHOTO-IODINATION OF CITRIC ACID IN AQUEOUS SOLUTION

BY J. L. MUKHERJEE AND C. M. KAKATI

Citric acid has been iodinated with aqueous iodine in presence of light at different temperatures and different concentrations of the acceptor and active molecules.

The reaction shows an induction period and there is a progressive diminution of the velocity constant with decrease in concentration of the acceptor molecules; but there is also an increase of the unimolecular constant with decrease in concentration of the active molecules.

In the previous paper (Mukherjee and Goswami, *J. Indian Chem. Soc.*, 1944, 21, 237) KI was avoided and the reaction was carried out with sodium tartrate with aqueous iodine and certain peculiarities were observed. Expecting that the same peculiarities would be observed in other photo-iodination process, the present piece of investigation was undertaken.

### EXPERIMENTAL

Resublimed iodine was mixed with  $\frac{1}{4}$  its weight of KI and sublimed again to remove traces of chlorine etc. This iodine was dissolved in conductivity water by shaking in a shaker. Pure Merck 'Extrapure' citric acid was dissolved in conductivity water. Equal volumes of solutions of iodine and citric acid, whose concentrations (before mixing) are given in each table, were mixed in the reaction vessel in a thermostat in the dark. Immediately 3 c. c. of the reaction mixture were withdrawn and titrated against approximately 0.001N- $\text{Na}_2\text{S}_2\text{O}_3$  by using a microburette. The source of light was a Point-o-lite lamp of 150 C. P. By keeping the centre of the lamp at a distance of 42.5 cm. from the reaction cell, the intensity of light was kept the same throughout the experiment. The mixture in the reaction cell was then exposed to light, made parallel by means of lens. Heat rays were cut off by allowing the light to pass through a filter of  $\text{N}/20\text{-CuSO}_4$ . At various intervals of time, measured by means of a stop watch, 3 c. c. of the reaction mixture were withdrawn and titrated as in the dark reaction.

Since after each withdrawal of 3 c. c. of the reaction mixture, a vacuum space occurred in which  $\text{I}_2$  could vaporise, and since it might diffuse through the reaction cell, it was first investigated whether there was any error due to these two factors; the escape of iodine due to these factors was found to be quite negligible.

Table XI gives the reaction rate in dark at 20°; the dark reaction is unimolecular.  $k$  is the unimolecular constant calculated according to the equation  $k = 1/t \log 10 \frac{a}{a-x}$ , where  $a$  represents the initial concentration of  $I_2$  and  $(a-x)$ , the concentration  $I_2$  after  $t$  minutes.

The reactions shown in Tables I to XI were carried at 20°, while those shown in Tables XIV and XV were carried at 30°. The temperature coefficients at two different concentrations of citric acid are shown in Table XVI.

TABLE I

Citric acid = 1M.  $I_2 = 0.1614N/50$ .  
Wratten filter blue used.

Time.	Thio.	$k$ .
0 min.	2.83 c.c.	
15	2.62	
30	2.44	0.00228
90	1.80	.00222
120	1.50	.00223
	Mean.	.00224

TABLE II

Citric acid = 0.5 M. Conc. of  
 $I_2$  and filter same as in Table I.

Time.	Thio.	$k$ .
0 min.	3.00 c.c. Induction	
10	3.00	period
30	2.78	0.00165
60	2.58	.00165
90	2.36	.00137
120	2.20	.00130
	Mean.	.00149

TABLE III

Citric acid = 0.25M.  $I_2$  and  
filter same as in Table I.

Time.	Thio.	$k$ .
0 min.	2.68 c.c. Induction	
15	2.68	period.
30	2.58	0.00110
60	2.40	.00109
90	2.22	.00109
	Mean	0.00109

TABLE IV

Citric acid = 0.125M.  $I_2$  and  
filter same as in Table I.

Time.	Thio.	$k$ .
0 min.	3.82 c.c. Induction	
15	3.82	period.
30	3.70	0.000928
60	3.48	.000900
120	2.96	.00105
	Mean	0.000959

TABLE V

Citric acid = 0.1M.  $I_2$  and filter  
same as in Table I

Time.	Thio.	$k$ .
0 min.	5.00 c.c. Induction	
15	5.00	period
30	4.84	0.000916
60	4.54	.000931
90	4.25	.000920
120	4.00	.000921
	Mean.	.000929

TABLE VI

Citric acid = 0.1M. Conc. of  
 $I_2 = 0.1614 N/80$ . Blue filter.

Time.	Thio	$k$ .
0 min.	8.43 c.c.	
15	3.33	
30	3.22	0.000960
45	3.12	.000940
60	3.01	.001073
90	2.82	.000962
	Mean	.000960

Tables II—V show an induction period.

TABLE VII

$I_2 = 0.1614 N/100$ .  
Citric acid and filter same as  
in Table VI.

Time.	Thio.	$k$ .
0 min.	2.28 c.c.	
15	2.20	
30	2.11	0.00112
60	1.98	.00101
90	1.86	.00121
	Mean	0.00114

TABLE VIII

$I_2 = 0.1614 N/160$ .  
Citric acid and filter same as  
in Table VI.

Time.	Thio.	$k$ .
0 min.	4.25 c.c. Induction period.	
15	4.25	
30	4.00	0.00168
60	3.65	.000147
90	3.28	.00150
105	3.04	.00161
	Mean	.00156

TABLE IX

$I_2 = 0.1614 N/200$ .  
Citric acid & filter same  
as in Table VI.

Time.	Thio.	$k$ .
0 min.	1.54 c.c. Induction period.	
10	1.54	
30	1.43	0.00161
45	1.35	.00163
60	1.28	.00160
90	1.06	.00161
	Mean	.00161

TABLE X

$I_2 = 0.1614 N/266$ . Citric acid  
& filter same as in Table VI.

Time.	Thio.	$k$ .
0 min.	2.22 c.c. Induction period.	
15	2.22	
30	2.22	
45	2.09	0.00175
60	1.96	.00180
75	1.85	.00176
	Mean	0.00177

TABLE XI

Citric acid &  $I_2$  same as in Table V.  
Dark reaction.

Time	Thio	$k$ .
0 min.	3.22 c.c.	
60	3.17	0.000118
145	3.10	.000114
295	3.02	.003094

TABLE XII

Variation of  $k$  with the  
decrease of conc. of active  
molecules ( $I_2$ ).  
Conc.  $k$  Ref.  
table.

0.1614 N/50	0.000929	V
.1614 N/80	.000960	VI
.1614 N/100	.00114	VII
.1614 N/160	.00156	VIII
.1614 N/200	.00161	IX
.1614 N/266	.00177	X

Induction period is observed in Tables VIII to X.

TABLE XIII

Variation of the value  $k$   
as the conc. of the acceptor  
molecules decreases.

Conc.	$k$ .	Reference Table.
0.1 M	0.00224	I
0.50	.00149	II
0.025	.00109	III
0.125	0.000959	IV
0.1	.000929	V

TABLE XIV

0.25 M-Citric acid 0.1614  
N/50-Iodine and blue filter,  
Temp.=30.

Time	Thio.	$k$ .
0 min	1.90 c.c. Induction period	
15	1.90	
30	1.76	0.00222
60	1.52	.00215
90	1.32	.00211
120	1.14	.00211

TABLE XV

0.1 M-Citric acid.  $I_2 = 0.1614$   
N/50 blue filter, Temp.=30°.

Time.	Thio.	$k$ .
0 min	2.46 c.c.	
20	2.22	
40	2.02	0.00205
60	1.83	.00204
90	1.60	.00203
	Mean	.00204

Mean .00215

TABLE XVI

Concentration of citric acid.	Iodine content.	$kt$ at 20°.	$k_{t+10}$ at 30°	Temp. coeff.  $\frac{k(t+10)}{k}$
0.25 <i>M</i>	0.1611 <i>N</i> /50	0.00109	0.00215	1.9
0.1 <i>M</i>	0.1614 <i>N</i> /50	.00093	.00204	2.2

The decrease of the unimolecular constant with increase in the concentration of the active molecules might be, we believe, ascribed to a greater chance of the active molecules being deactivated by collision with other unactivated molecules of the same species present inside the solution on account of the greater proximity of these (unactivated) molecules to the active molecules present at higher than at lower concentration.

Our thanks are due to Prof. J. B. Sarkar, the Head of the Chemistry Dept. for the kind sympathy and facilities afforded to us for carrying out this piece of work.

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# STUDIES IN CELLULOSE ACETATE. PART III.

BY PIJUSH KANTI CHOUDHURY

Identical results as reported in part II of this paper have been obtained by using different proportions of cellulose and acetylating mixtures.

In Part II of this series (*This Journal*, 1947, 24, 271) the author gave results of acetylation where a certain proportion of cellulose and acetylating mixture, namely C : Ac : An = 1 : 5 : 4 (C=cellulose, Ac=glacial acetic acid, An=acetic anhydride) was always maintained. The only variable was the percentage of  $H_2SO_4$  used as a catalyst, the reaction temperature being the same in all the experiments undertaken. Practically identical results were obtained using different percentages of  $H_2SO_4$  as catalyst, maintaining the same proportion of cellulose and acetylating mixture.

Further investigations reveal that identical results can be obtained even by using different proportions of cellulose and acetylating mixture, as will be evident from the tables given below. The abbreviations used signifying the degree of solubility are the same as used in Part II (*loc. cit.*). S=soluble; I S.=insoluble; L. S.=less soluble; M. S.=moderately soluble; P. S.=partly soluble; C. S.=completely soluble; P=plastic.

TABLE I

Expt. No. 7. Cellulose : acetic acid : acetic anhydride = 1 : 5 : 3. Catalyst = 12.9%  $H_2SO_4$ .

No. of sample.	Duration of reaction (total hrs.)	*Period of hydrolysis (total hrs.)	Solubility at room temp. in		Acetic acid content.
			Chloroform.	Acetone.	
1.	6.0	x	M. S.	Swelling	62.4%
2.	8.0	x	S.	P. S.	61.2
3.	24.0	x	C. S.	C. S.	58.8
4.	27.0	2	"	"	56.4
5.	30.0	5	L. S.	"	55.2
6.	32.0	7	P.	"	54.0
7.	48.5	23.5	I. S.	"	48.6
8.	52.0	27.0	"	S. but not easily	48.0
9.	55.0	30.0	"	L. S.	47.4

Expt. No. 8. C : Ac : An = 1 : 4 : 4. Catalyst = 12.9%  $H_2SO_4$ .

1.	6.0	x	M. S.	I. S.	61.8
2.	8.0	x	S.	P. S.	61.2
3.	24.0	x	C. S.	C. S.	58.8
4.	27.0	2.5	L. S.	"	55.2
5.	30.0	5.5	P.	"	54.6
6.	32.0	7.5	P.	"	54.0
7.	48.0	23.5	I. S.	S.	48.7
8.	55.0	30.5	"	I. S.	46.3

Expt. No. 9. C : Ac : An = 1 : 5 : 4. Catalyst = 18.4%  $H_2SO_4$ .

1.	4	x	S. but not easily	I. S.	62.4
2.	6	x	M. S.	"	61.8
3.	8	x	S.	P. S.	61.2
4.	10	x	C. S.	S.	60.6
5.	12	x	"	C. S.	60.0
6.	24	x	"	"	58.8
7.	26	2	"	"	58.2
8.	28	4	"	"	57.6
9.	30	6	L. S.	"	55.1
10.	32	8	P.	"	54.0
11.	34	10	I. S.	"	52.7

\* after the addition of 65% acid

TABLE II

Expt. No. 7. C : Ac : An = 1 : 5 : 3. Catalyst = 12.9% $H_2SO_4$ .					
No. of sample,	Duration of reaction (total hrs.)	*Period of hydrolysis (total hrs.)	Solubility at room temperature in		Acetic acid content.
			Chloroform.	Acetone.	
3.	24	×	C.S.	C.S.	58.8%
4.	28	4	"	"	57.6
5.	32	8	P.	"	54.0
6.	48	24.5	L.S.	"	48.6
7.	55	31.0	"	"	47.2
Expt. No. 8. C : Ac : An = 1 : 4 : 4. Catalyst = 12.9% $H_2SO_4$ .					
3.	24	×	C.S.	C.S.	58.8
4.	28	4	L.S.	"	55.8
5.	32	8	P.	"	54.0
6.	48	24	L.S.	"	48.7
7.	55	31	"	L.S.	47.3
Expt. No. 9. C : Ac : An = 1 : 5 : 4. Catalyst = 18.4% $H_2SO_4$ .					
6.	24	×	C.S.	C.S.	58.8
7.	26	2	"	"	58.2
8.	28	4	S.	"	57.6
9.	30	6	L.S.	"	56.4
10.	32	8	P.	"	54.4
11.	34	10	L.S.	"	52.7

\* Without the addition of 65% acid or water.

TABLE III

Expt. No. 9. C : Ac : An = 1 : 5 : 4. Catalyst = 12.9% $H_2SO_4$ .					
No. of sample,	Duration of the reaction (total hrs.)	*Period of hydrolysis (total hrs.)	Solubility at room temperature in		Acetic acid content.
			Chloroform.	Acetone.	
1.	4	×	S. but not easily	I.S.	62.4%
2.	6	×	M.S.	"	61.8
3.	23	2	C.S.	C.S.	57.0
4.	25	2	"	"	56.4
5.	27	4	"	"	55.8
6.	29	6	L.S.	"	55.2
7.	31	8	P.	"	53.5

\* Without the addition of 65% acid or water, but maintaining at a temperature of 40-45°.

TABLE IV

No. of experiment.	No. of sample.	Period of reaction in hrs. (Z)	% of H <sub>2</sub> SO <sub>4</sub> used as catalyst.	Ratio of (C : Ac : An)	% Acetic acid content mean expt. value.	calc. from formula.	% Diff. between the two.	REMARKS.
5,9,10	1,1,1	4	18,4,18,4,12,9	1 : 5 : 4	62.4	62.4	Nil	
3,4,5,6 7,8,9,10	1,1,1,1 1,1,2,2	6	14,7,16,8,18,4 20,2,12,9,12,9 18,4,12,9	1 : 5 : 4 (for Nos. 3,4,5,6,9,10) 1 : 5 : 3 (for No. 7) 1 : 4 : 4 (for No. 8)	62.1	61.8	+0.5	
3,4,5,6, 7,8,9	2,2,3,2 2,2,3	8	Do.	Do	61.3	61.2	+0.2	
9 9 10	4 5 3	10 12 23	18,4 Do. 12,9	1 : 5 : 4 Do Do	60.6 60.0 57.0	60.6 60.0 56.7	Nil Nil +0.5	In this case the solution was kept overnight at 40-45°.
3,5,6,7, 8,9	3,4,3,3, 2,6	24	14,7,18,4,20,2, 12,9,12,9,18,4	1 : 5 : 4 (for Nos. 3,5,6,9) 1 : 5 : 3 (for No. 7) 1 : 4 : 4 (for No. 8)	58.8	56.4	+4.3	As the solution was kept overnight at ordinary temperature (30-32°) instead of 40-45° the reaction slowed down.
3,10, 3,5,6,	4,4, 5,5,4	25 26	14,7,12,9 14,7,18,4,20,2	1 : 5 : 4 Do	57.6 57.6	56.1 55.8	+2.6 +3.2	
1,2,7 3,10	1,1,4 4,5	27	11,0,12,9,12,9 12,9,12,9	1 : 5 : 4 (for Nos. 1,2 & 10) 1 : 5 : 3 (for No. 7) 1 : 4 : 4 (for No. 8)	55.8	55.5	+0.5	

TABLE IV. (continued)

No. of experiment.	No. of sample.	Period of reaction in hrs. (Z).	% of H <sub>2</sub> SO <sub>4</sub> used as catalyst.	Ratio of (C : Ac : An)	% Acetic acid content mean expt. value.	calc. from formula.	% Diff. between the two.	REMARKS.
3.5.6.9.	7.6.5.8.	28	14.7, 18.4, 20.2, 18.4.	1 : 5 : 4	55.6	55.2	+0.5	
10.	6	20	12.9	Do	55.2	54.9	+0.5	
3.6.7.8	8.6.5.5	30	14.7, 20.2, 12.9, 12.9, 18.4.	1 : 5 : 4 (for Nos. 3, 6, 9)				
				1 : 5 : 3 (for No. 7)	54.3	54.6	-0.5	
				1 : 4 : 4 (for No. 8)				
3.5.6.7, 8, 10.	9.7.7.6, 6, 10.7.	32	14.7, 18.4, 20.2, 12.9, 12.9, 18.4, 12.9.	1 : 5 : 4 (for Nos. 3, 5, 6, 9, 10)	53.7	54.0	-0.5	
				1 : 5 : 3 (for No. 7)				
				1 : 4 : 4 (for No. 8)				
3.5.6.7, 8.	11.8.8.7, 7.	48	14.7, 18.4, 20.2, 12.9, 12.9.	1 : 5 : 4 (for Nos. 3, 5, 6)	48.5	49.2	+1.4	
				1 : 5 : 3 (for No. 7)				
				1 : 4 : 4 (for No. 8)				
3.6.7.8	12.9.9.8	56	14.7, 20.2, 12.9, 12.9.	1 : 5 : 4 (for Nos. 3 & 6)				
				1 : 5 : 4 (for No. 7)				
				1 : 4 : 4 (for No. 8)	46.5	47.1	+1.3	



In the previous paper (*loc cit.*) it was postulated that the hydrolysis of tri-acetates to di-acetates could be brought about without the presence of dilute acetic acid or water, the only difference observed between the one hydrolysed in the usual way and the other hydrolysed without the addition of water, being longer hours, required by the latter to give the same product or products. Further investigations have revealed that if the temperature of 40-45° is maintained throughout the experiment then the longer hours, as postulated to be required by the product hydrolysed without the addition of water, can be so effectively minimised that the hydrolysis may produce the identical, lowering down in the percentage content of acetic acid of the acetate. Results shown in Tables I and II justify this postulate.

If the results of these tables, as well as those of the Part II (*loc cit.*) are scrutinized, it will be observed that the percentage acetic acid content of the acetate bears a definite relation with the period of reaction during and after acetylation. This relation holds good in practically all the results obtained, irrespective of the ratio of cellulose and acetylating mixture as well as that of the percentage of  $H_2SO_4$  used as catalyst. Further observation reveals that the percentage of acetic acid content in between the two definite hours of reaction, say between 4 and 8 hours or 28 and 32 hours, is lowered down by a constant or a multiple of a constant, which has been found to be a figure near about 1.2. This has led the author for the process of acetylation, in all probability, to formulate a simple linear reaction, guided by the following formula,

$$Y = C + 1.2 X \text{ and}$$

$$X = \frac{1}{4}(C + 4 - Z)$$

where  $Y$  = % acetic acid content of cellulose acetate,

$X$  = degree of acetylation,

$Z$  = total hours of reaction, and

$C$  = a constant, namely 48, which is the % acetic acid content of a true di-acetate.

Now if  $Z$  is known, we can easily find out the value of  $X$  and from that  $Y$  may be easily evaluated.

The results given in Table IV postulate a very close relation between the percentage acetic acid of an acetate with the period of reaction. This also justifies to a great measure the assumption and validity of the mathematical expression, as proposed. Excepting two cases, namely when the period of reaction is 24 and 26 hours, the difference between the experimental and calculated results is very small, namely 0.5% only, which may be easily overlooked. The bigger differences in the two cases, cited above, may be due, according to the author

to keeping the solution overnight at ordinary temperature (30-32°) instead of at 40-45°, the optimum temperature of the reaction. This assumption is substantiated by the fact that in the case of reaction period of 23 hours, the difference is only +0.5%. Further, as temperature is gradually raised and kept at 40-45° from 24th hour to 27th, the difference observed is again small, namely 0.5% in the latter cases.

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## SYNTHESIS OF SUBSTITUTED DINITROPHENYL KETONES AND PHENYLACETIC ACIDS. PART II.

BY A. B. SEN AND P. M. BHARGAVA

2 : 6-Dinitro-4-bromophenyl-acetone and -acetic acid have been prepared.

In the previous part of this series (*this Journal*, 1947, 24, 268) it has been shown that substituted phenylketones and phenylacetic acids can be obtained in good yields by submitting the condensation products of acetoacetic ester and polynitro aromatic compounds containing reactive halogen atom to ketonic and acid hydrolysis respectively.

In the present paper this reaction has been extended to the preparation of 2 : 6-dinitro-4-bromophenylacetone and 2 : 6-dinitro-4-bromophenylacetic acid.

### EXPERIMENTAL

**2 : 6-Dinitro-4-bromophenylacetoacetic Ester.**—Ethyl acetoacetate (5.2 c.c.) was added, with stirring, to 0.92 g. of sodium and 20 c.c. of ether contained in a bolt-head flask fitted with a condenser and a mechanical stirrer. This was heated on the water-bath until the last traces of sodium had disappeared. To the cooled solution was added 1-chloro-4-bromo-2 : 6-dinitrobenzene (5.6 g.), the mixture refluxed for 6 hours with constant stirring and then allowed to stand for 12 hours. The ethereal solution was first extracted with water and then with 1% sodium hydroxide; the combined extracts were then acidified with dilute nitric acid, when a red oil separated out. The aqueous layer was decanted, the residual oil dissolved in an excess of cold alcohol and then left for crystallisation. Two crops of crystals were obtained on partial evaporation of the alcohol. The first crop consisted of yellow and the second, of dark red crystals. These two crops of crystals were combined and further purified by the same method when yellow needles were obtained, m. p. 97°, yield 98% of theory. (Found : N, 7.47.  $C_{12}H_{11}O_7N_2Br$  requires N, 7.25 per cent).

**2 : 6-Dinitro-4-bromophenylacetone.**—Finely powdered 2 : 6-dinitro-4-bromophenylacetoacetic ester (1.5 g.) was dissolved in 15 c.c. of concentrated sulphuric acid and 7 c. c. of water were then added to it under constant stirring. A brisk evolution of  $CO_2$  commenced; when the evolution of  $CO_2$  had ceased, the solution was poured on ice. The ketone which separated out was filtered and recrystallised from hot alcohol as colourless needles, m. p. 133-34°, yield quantitative. (Found : N, 9.47.  $C_9H_7O_5N_2Br$  requires N, 9.24 per cent).

**The phenylhydrazone** was prepared by dissolving the above ketone (0.5 g.) in about 10 c.c. of alcohol and adding to it about 8 drops of phenylhydrazine and refluxing the mixture for 15 minutes. The phenylhydrazone separated out from this solution on cooling. Recrystallised from hot alcohol as fine yellow needles it melts at 126-27°, yield theoretical. (Found : N, 14.17.  $C_{15}H_{13}O_4N_4Br$  requires N, 14.25 per cent).

The *oxime* was prepared by adding 0.5 g. of hydroxylamine sulphate to a solution of the above ketone (1 g.) in alcohol, and a drop of phenolphthalein, followed by a solution of caustic soda dropwise until a permanent red colour was obtained. This mixture was refluxed for about an hour, cooled, and then poured in 30 c.c. of water, and left in a refrigerator overnight. The precipitate which separated out was filtered and washed with cold alcohol, when a yellow crystalline product was left behind, m. p. 93-94°, yield 75% of theory. (Found : N, 12.78.  $C_9H_8O_5N_3Br$  requires N, 13.20 per cent).

2 : 6-Dinitro-4-bromophenylacetic Acid.—2 : 4-Dinitro-4-bromophenylacetoacetic ester (1 g.) was refluxed for half an hour with 5 c.c. of 20% alcoholic potash. The alcohol was then distilled off and the residue acidified with dilute HCl, when a solid product separated out. This was dissolved in hot alcohol, filtered, and the filtrate allowed to evaporate. The first crop consisted of yellowish needles of the unchanged ester and was rejected. The second crop, obtained as brown scales of m. p. 184°, proved to be the desired acid, yield 80% of theory. (Found : N, 8.87.  $C_8H_5O_6N_2Br$  requires N, 9.18 per cent).

2 : 6-Dinitro-4-bromophenylmalonic Ester.—To the sodium derivative of ethyl malonate, prepared from sodium (0.92 g.) and malonic ester (6.4 g.) in 25 c.c. of ether, was added 5.6 g. of 1-chloro-2 : 6-dinitro-4-bromobenzene, suspended in ether. The mixture was refluxed for 6 hours and allowed to stand overnight. The ethereal mixture was extracted first with water and then with 1% NaOH and the combined extracts acidified with dilute nitric acid, when a red oil separated. The aqueous portion was decanted, the oil dissolved in alcohol and left to crystallise by itself. Recrystallisation was effected by redissolving it in alcohol, filtering and allowing the filtrate to evaporate, when brownish red needles were obtained, m. p. 101°, yield 90% of theory. (Found : N, 6.88.  $C_{13}H_{12}O_8N_2Br$  requires N, 6.91 per cent).

2 : 6-Dinitro-4-bromophenylacetic Acid.—The above ester (2 g.) was dissolved in acetic acid (6 c.c.), and a mixture of 15 c.c. of water and 1 c.c. of conc. sulphuric acid was added to it. It was hydrolysed on a free but low flame for two hours under a reflux condenser when the colour of the mixture changed to dark brown and then to red. On cooling in ice, the acid separated out which was then allowed to settle. The supernatant liquid was decanted off, the residue in the flask dissolved in alcohol and the solvent allowed to evaporate when the acid crystallised out, yield 90% of theory, m. p. 184° (identical with the m. p. of the acid obtained by hydrolysis of 2 : 6-dinitro 4-bromophenylacetoacetic ester). (Found : N, 8.51.  $C_8H_5O_6N_2Br$  requires N, 9.18 per cent).

## A NOTE ON THE FRIEDEL AND CRAFT'S CONDENSATION OF ACETYL CHLORIDE WITH DICHLOROBENZENES

BY K. C. KSHATRIYA, N. S. SHODHAN AND K. S. NARGUND

Dichlorobenzenes have been successfully condensed with acetyl chloride to obtain dichloroacetophenones. The products have been characterised by the usual derivatives and oxidised to dichlorobenzoic acids

Dichloroacetophenones were required in this laboratory in connection with work on substituted chalcones and acridines. The easiest method of obtaining these would be by the Friedel and Craft's condensation of acetyl chloride with dichlorobenzenes. Previous attempts by various workers in this direction have been unsuccessful. Thus Boesekin (*Rec. trav. chim.*, 1908, 27, 10) found that the condensation of acetyl chloride with *o*-, *m*- and *p*-dichlorobenzenes gave 2%, 0.4% and nil yields of the corresponding acetophenones. He attributed this failure to the self-condensation of acetyl chloride (Combes reaction). Benzoyl chloride, which does not undergo self-condensation, on the other hand, gave with *o*- and *m*-dichlorobenzenes 80 to 90% of dichlorobenzophenones. *p*-Dichlorobenzene, however, gave only a tarry product. Roberts and Turner (*J. Chem. Soc.*, 1927, 1832) condensed acetyl chloride with *o*-dichlorobenzene and obtained 40% yield of 3:4-dichloroacetophenone. We have now reinvestigated the condensation of acetyl chloride with dichlorobenzenes with the following results.

Good yields of dichloroacetophenones from the three isomeric dichlorobenzenes can be obtained if the condensations are carried without any solvent and with an excess of acetyl chloride and aluminium chloride. The best conditions for obtaining the maximum yields are one part of dichlorobenzene, one part of acetyl chloride and two parts of anhydrous aluminium chloride, heated together on a water-bath for 5 hours. Under these conditions *o*-dichlorobenzene gives 90% yield (the yields in all cases have been calculated on the quantity of dichlorobenzene used in the experiments without making allowance for the recovered dichlorobenzene) of 3:4-dichloroacetophenone, m. p. 75°; Roberts and Turner (*loc. cit.*) record the m. p. 76°. It has been characterised by formation of an oxime, semicarbazone, phenylhydrazone and 2:4-dinitrophenylhydrazone.

*m*-Dichlorobenzene under the condition gives 70% yield of 2:4-dichloroacetophenone (b. p. 235-240° at ordinary pressure). It solidifies later, m. p. 42°. It gives an oxime, semicarbazone, and 2:4-dinitrophenylhydrazone. On oxidation with either alkaline potassium permanganate or sodium hypobromite a quantitative yield of 2:4-dichlorobenzoic acid (m.p. 164°) is obtained.

*p*-Dichlorobenzene gives 50% yield of 2:5-dichloroacetophenone b. p. 245-250°, characterised by an oxime, semicarbazone and 2:4-dinitrophenylhydrazone. On oxidation it gives 2:5-dichlorobenzoic acid, m. p. 152°.

The good yields in the condensation of acetyl chloride with dichlorobenzenes and the quantitative oxidation of the resulting dichloroacetophenones to the corresponding dichlorobenzoic acids can, hence, be used to prepare the dichlorobenzoic acids which are otherwise difficult to obtain.

With a view to finding the best conditions a number of experiments were made with *o*-dichlorobenzene, the reactants being heated together on a water-bath for 5 hours. Ice and hydrochloric acid were added and steam distilled. The product recovered by ether extraction was purified by fractionation. The results are shown in the following table.

TABLE I

<i>o</i> -Dichlorobenzene.	Acetyl chloride.	Solvent.	AlCl <sub>3</sub> .	Yield of dichloroacetophenone.
10 g.	10 g.	CS <sub>2</sub> (40 c. c.)	30 g.	16%
10	10	No solvent	40	90
10	10	" "	20	90
10	10	" "	10	20
10	5	" "	20	8

Adam and Noller's modification, namely the use of acetic anhydride in place of acetyl chloride (*J. Amer. Chem. Soc.*, 1924, 46, 1889) was not satisfactory as the yield was about 20% only. 3 : 4-Dichloroacetophenone formed an *oxime*, as glistening needles from alcohol, m. p. 110°. (Found : Cl, 34.6. C<sub>8</sub>H<sub>7</sub>ONCl<sub>2</sub> requires Cl, 34.8 per cent). The *semicarbazone* crystallised from alcohol in needles, m. p. 250°. (Found : Cl, 29.2. C<sub>9</sub>H<sub>9</sub>ON<sub>3</sub>Cl<sub>2</sub> requires Cl, 28.9 per cent). The *phenylhydrazone* crystallised in pale yellow shining plates, m. p. 122-24°. (Found : Cl, 25.9. C<sub>14</sub>H<sub>12</sub>N<sub>2</sub>Cl<sub>2</sub> requires Cl 25.5 per cent)

2 : 4-Dichloroacetophenone had b. p. 235-240°.  $D_4^{25} = 1.322$ ;  $n_D^{25} = 1.5606$ . It solidified later and had m. p. 42°. (Found : Cl, 37.8. C<sub>8</sub>H<sub>6</sub>OCl<sub>2</sub> requires Cl, 37.6 per cent). It gave an *oxime* as prismatic needles from alcohol, m. p. 152°. (Found : Cl, 34.9. C<sub>8</sub>H<sub>7</sub>ONCl<sub>2</sub> requires Cl, 34.8 per cent). The *semicarbazone* crystallised from alcohol in needles, m. p. 208°. (Found : Cl, 28.8. C<sub>9</sub>H<sub>9</sub>ON<sub>3</sub>Cl<sub>2</sub> requires Cl, 28.9 per cent). On oxidation it gave 2 : 4-dichlorobenzoic acid, m. p. 164°.

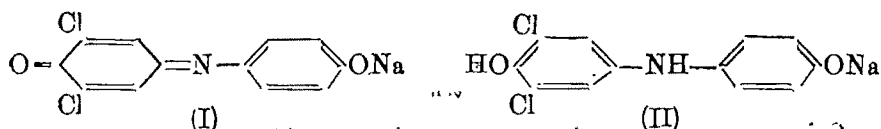
2 : 5-Dichloroacetophenone had b. p. 245-250° at ordinary pressure. It had  $D_4^{17.5} = 1.352$ ;  $n_D^{17.5} = 1.5595$  (Found : Cl, 38.1. C<sub>8</sub>H<sub>6</sub>OCl<sub>2</sub> requires Cl, 37.6 per cent.) It formed an *oxime* as long, thin, woolly needles, m. p. 127° (Found : Cl, 34.3. C<sub>8</sub>H<sub>7</sub>ONCl<sub>2</sub> requires Cl, 34.8 per cent) The *semicarbazone* crystallised from alcohol in needles, m. p. 202-203°. (Found : Cl, 29.3. C<sub>9</sub>H<sub>9</sub>ON<sub>3</sub>Cl<sub>2</sub> requires Cl, 28.9 per cent). On oxidation it gave 2 : 5-dichlorobenzoic acid, m. p. 152°.

## SODIUM 2:6-DICHLOROINDOPHENOLATE

BY G. S. APTE AND T. B. PANSE

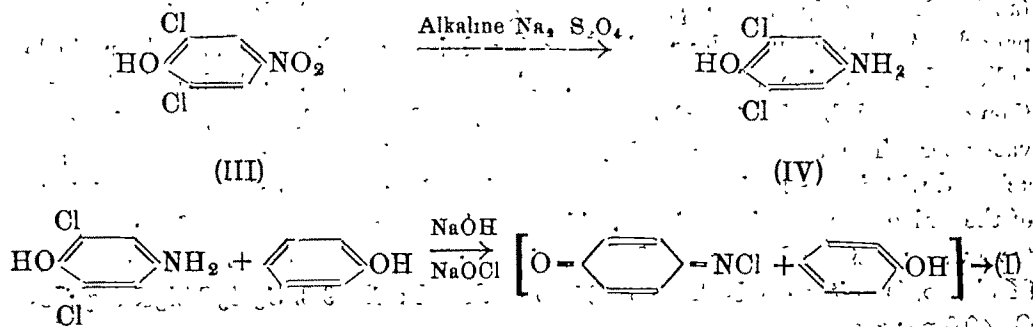
2:6-Dichloro-4-aminophenol, obtained in quantitative yield by alkaline hydrosulphite reduction of the corresponding nitrophenol, has been condensed with phenol in presence of sodium hypochlorite to form the sodium 2:6-dichlorophenol-indophenol dye in high yield, obviating the isolation of the intermediate 2:6-dichloroquinone chlorimide.

The sodium salt of 2:6-dichlorophenol-indophenol is a redox indicator used specifically in the determination of vitamin-C in biological materials. The deep blue aqueous solution of the dye (I) is quantitatively reduced to its leuco base (II), ascorbic acid itself being oxidised to dehydroascorbic acid.



In the course of investigations on the biosynthesis of vitamin-C in plants (Panse and Sreenivasan, *Curr. Sci.*, 1945, 14, 303) difficulty was experienced in obtaining the dye; the only available commercial sample, supplied as tablets and specified to contain a certain amount of the dye, was found to have undergone considerable deterioration. Recourse was therefore taken to synthesise the dye.

Tillmans *et al.* (*Univ. Frankfurt a.m. Z. unters Lebensm.*, 1928, 56, 272) prepared the indicator by coupling a solution of 2:6-dichloroquinone chlorimide with phenol in presence of aqueous alkali. This synthesis has been repeated under similar conditions by Gibbs *et al.* (U. S. Pub. Health Rep., 1929, suppl. No. 69, p. 35), Ven Hoo *et al.* (*Sci. Rep. Nat. Tsinghua Univ.*, 1934, 2A, 235) and Mikhailov (*Trans. Inst. Pure Chem. Reagents USSR.*, 1939, 17, 45). However, there is little published work detailing the exact conditions by which the synthesis of the dye could be carried out. The scheme used for its preparation in this laboratory may be represented as follows.



*p*-Nitrophenol is chlorinated with chlorate-chloride mixture to form 2:6-dichloro-4-nitrophenol (III) (Kollrep, *Annalen*, 1886, 234, 8). Alkaline hydrosulphite reduction of (III) gives the corresponding aminophenol (IV) in quantitative yield (Kollrep, *loc. cit.*) and the method is simpler and less time-consuming than the procedure of Mikhailov (*Trans. Inst. Pure Chem. Reagents USSR*, 1939, 16, 83) employing tin and hydrochloric acid. Addition of sodium hypochlorite solution to an alkaline solution of phenol, mixed with (IV), results in the formation of (I) in one stage and in about 80% yield. The synthesis of the dye in high yield is thus possible without isolation of the intermediate 2:6-dichloroquinone chlorimide, as reported by Gibbs (*loc. cit.*).

## EXPERIMENTAL

*Chlorination of p-Nitrophenol.*—*p*-Nitrophenol (22 g.) was dissolved in commercial hydrochloric acid (1000 c.c.). The solution was warmed and insoluble matter, if any, was filtered off. The solution was then poured in a filter-flask of about two litre capacity, fitted with a separating funnel containing the potassium chlorate solution (16 g in 300 c.c. of water) and the side-tube attached to the water-pump for absorbing hydrochloric acid fumes. The potassium chlorate solution was gradually added with constant stirring to the reaction mixture during a period of about 20 minutes when the dichloro compound separated. The reaction liquid was then cooled in a refrigerator for some time and filtered. The product crystallised from water in the form of light yellow plates, m.p. 125°, yield 27 g. (76% of theory).

*Reduction of 2:6-Dichloro-4-nitrophenol*—2:6-Dichloro-4-nitrophenol (25 g.) was dissolved in 10% sodium hydroxide solution (1250 c.c.) by heating to 80-90°. To the solution was gradually added sodium hydrosulphite (100 g.) during a period of about 20 minutes maintaining the temperature of the solution at 80°. The solution was kept alkaline throughout the reaction (tested intermittently with phenolphthalein paper for alkalinity and for hydrosulphite with vat paper). A change in colour of the original brown solution to a lighter shade indicated completion of the reaction. Excess of the sodium hydrosulphite was then destroyed by boiling the solution until it did not show any reaction with vat-paper. The solution was then allowed to attain the room temperature and acidified with just sufficient amount of acetic acid when a crystalline precipitate of the amine separated immediately. The precipitate was filtered and crystallised from water as fine colourless needles turning gray on exposure to light, m.p. 165° (Kollrepp, *loc. cit.*, records the m.p. 165-66°). (Found: Cl, 39.8.  $C_6H_5OCl_2N$  requires Cl, 40.0 per cent).



The amine being unstable was immediately used for the next reaction.

*Condensation of 2 : 6-Dichloro-4-aminophenol with Phenol in presence of Sodium Hypochlorite and Formation of the Sodium 2 : 6-Dichloroindophenolate (I).—*The sodium hypochlorite was prepared by passing chlorine in 10% sodium hydroxide solution, surrounded by ice-salt mixture ( $-10^{\circ}$ ) till saturated. The hypochlorite solution was found to contain 45 g. per litre of available chlorine and was freshly prepared every time.

2 : 6-Dichloro-4-aminophenol (9 g.) and phenol (72 g.) were taken in a flask, immersed in an ice-bath and sodium hypochlorite solution was gradually added to it with constant stirring. Soon lustrous, green, tiny needles of sodium 2 : 6-dichloroindophenolate began to separate. The solution was then allowed to stand in the refrigerator. The product was filtered and crystallised from brine (200 g. NaCl per litre) water. Second crystallisation (charcoal) improved the lustre of the product. The product was dried at  $40^{\circ}$  under vacuum, yield 10.3 g. (80% of theory). The dye was tested for its purity by standardisation against ascorbic acid according to the methods of Harris and Oliver (*Biochem. J.*, 1942, 36, 176) and Guerrant (*Ind. Eng. Chem. Anal. Ed.*, 1938, 10, 25), and was found to have the same standard of purity as the commercial samples.

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# PHOTOBROMINATION OF CAMPHOR AND THE INFLUENCE OF DIFFERENT SOLVENTS ON THE REACTION

BY P. C. GOSWAMI

The photobromination of camphor has been carried out in  $\text{CCl}_4$ ,  $\text{C}_6\text{H}_6$ ,  $\text{CS}_2$  and  $\text{CHCl}_3$  in light. In all the media the reaction is strictly unimolecular. In dark, at temperatures not exceeding  $30^\circ$ , the reaction does not take place at all. There is no period of induction or photochemical after-effect. The velocity constants and the temperature coefficients vary widely in different solvents. No direct relationship can be found between the velocity constants and the dielectric constants of the solvents and between the temperature coefficients and the dielectric constants.

The increase of velocity constant with decrease in the concentration of  $\text{Br}_2$  molecules is peculiar as it apparently violates Maxwell's law.

Camphor is found to take up bromine in presence of light. In dark, at temperatures not exceeding  $30^\circ$ , the reaction does not take place at all. Camphor is also soluble in many organic solvents. The effect of different solvents on the reaction and its kinetics are hence suitable fields for investigation.

The influence of solvents on photochemical reaction has been investigated by various workers. Winther (*Z. physikal. Chem.*, 1926, 120, 234) concluded that the velocity of photochemical reactions decreased as the dielectric constants of the solvents increased. In thermal reactions, however, reverse behaviour was observed. Many workers showed that no direct relationship could be obtained between the velocity coefficients and the dielectric constants of the solvents (Dhar, "Chemical Action of Light", p. 364; Mathur, Gupta and Bhatnagar, *Indian J. Phys.*, 1928, 2, 243; Yajnik and Uppal, *J. Indian Chem. Soc.*, 1929, 6, 729; Lauer *et al.*, *Ber.*, 1936, 69B, 137, 141, 851, 978, 1061; 1937, 70B, 326, 1288, 1707).

The presence of double linkages in the solvents has an accelerating action on the rate of reaction. Thus the photochemical reaction of anthracene  $\rightleftharpoons$  dianthracene and also photobromination of anthracene are greater in benzene than in other media. The photoreaction is also found to be parallel to the absorption spectra in the solvent. All these show that the dielectric constant of the solvents is not the single rate-determining factor.

Although several papers have been published, yet the photoreactions in different solvents are still not numerous. Photobromination of camphor has therefore been carried out in  $\text{CCl}_4$ ,  $\text{C}_6\text{H}_6$ ,  $\text{CS}_2$  and  $\text{CHCl}_3$ . Diethyl ether was also tried; but it was found to be an unsuitable solvent, as the medium itself had undergone bromination at a rate even higher than the rate of bromination of camphor.

## E X P E R I M E N T A L

Pure, resublimed synthetic camphor and Merck's pure bromine were taken. The solvents  $C_6H_6$ ,  $CCl_4$ ,  $CHCl_3$  and  $CS_2$  were samples from Merck, Baird and Tatlock, London, Boots Pure Drug Co., Nottingham and from Bengal Chemical and Pharmaceutical Works respectively. They were further distilled before use. The reaction was carried out in a stoppered glass cell. The reactants were mixed in dark and 2 c.c. of the mixture withdrawn immediately for initial reading. The cell was then exposed to the light of a Point-o-lite lamp of 150 c.p. made parallel by a lens. Heat rays were cut off by  $N/20$ - $CuSO_4$  solution. The reaction cell was kept in a double-walled thermostat having a window to allow light in. By keeping the reaction cell from the source of light at a distance of 42.5 cm. the intensity was kept constant. At various intervals of time, noted by a stop-watch, 2 c.c. of the mixture were withdrawn and after adding KI to the mixture, were titrated with approximately  $N/100$ -thiosulphate solution from a microburette. The velocity constant  $k$  was calculated from the equation,

$$k = \frac{1}{t} \log_{10} \frac{a}{a-x}$$

The reaction obeys the unimolecular equation as will be seen from the following tables. The concentration given always denotes the final concentration after the reactants are mixed.

TABLE I

Solvent=benzene,  $Br_2$  conc.= $N/37.24$ . Camphor conc.= $M/20$ . Temp.= $80^\circ$ .

Time (min.) ..	0	30	60	90	120	Light cut off	150
Thio (c.c.) ...	5.38	4.96	4.56	4.24	4.00		4.00
$k$ ...		0.00118	0.00119	0.00115	0.00107		Mean. 0.00115

TABLE II

Solvent= $CCl_4$ . Other conditions same as in Table I.

Time (min.) ...	0	45	80	115	150	Light cut off	180
Thio (c.c.) ...	5.12	4.68	4.36	4.08	3.80		3.80
$k$ ...		0.000868	0.000870	0.000856	0.000863		Mean. 0.000864

TABLE III

Solvent= $CS_2$ . Other conditions same as in Table I.

Time (min.) ...	0	60	136	196	256	Light cut off	300
Thio (c.c.) ...	5.74	5.64	5.52	5.42	5.34		5.38
$k$ ...		0.000126	0.000125	0.000122	0.0001222		Mean. 0.000124

TABLE IV

Solvent = $\text{CHCl}_3$ , Other conditions same as in Table I.							
Time (min.) ...	0	45	90	135	165	Light out off	195
Thio (c.c.) ...	4.71	4.47	4.25	4.04	3.90		3.91
$k$ ...		0.000604	0.000495	0.000493	0.000496		Mean, 0.000497

TABLE V

*Velocity constants in different media at 20° & 30°.*

Medium.	$k(20^\circ)$ .	$k(30^\circ)$ .	Temp. coeff.
$\text{C}_6\text{H}_6$	0.00086	0.00115	$\frac{0.00115}{0.00086} = 1.388$
$\text{CCl}_4$	0.000385	0.000864	$\frac{0.000864}{0.000385} = 2.245$
$\text{CS}_2$	0.000071	0.000124	$\frac{0.000124}{0.000071} = 1.746$
$\text{CHCl}_3$	0.000337	0.000497	$\frac{0.000497}{0.000337} = 1.475$

TABLE VI

*Relation of the dielectric const. of the solvents with velocity const. and with temp. coeff.*

Medium.	Dielec. const.	$k^{30^\circ}$ .	Temp. coeff.
$\text{CCl}_4$	2.25	0.000864	2.245
$\text{C}_6\text{H}_6$	2.29	0.00115	1.388
$\text{CS}_2$	2.61	0.000124	1.746
$\text{CHCl}_3$	5.14	0.000497	1.475

TABLE VII

*Reaction rate with diff. conc. of  $\text{Br}_2$ .*Conc. of camphor =  $M/20$ 

Medium.	Conc. of $\text{Br}_2$ .	$k^{20^\circ}$ .	Medium.	Conc. of $\text{Br}_2$ .	$k^{30^\circ}$ .
$\text{CCl}_4$	$N/37.24$	0.000885	$\text{CS}_2$	$N/37.24$	0.000071
	$N/74.48$	0.000440		$N/74.48$	0.000095
$\text{C}_6\text{H}_6$	$N/37.24$	0.00086	$\text{CHCl}_3$	$N/37.24$	0.000497
	$N/74.48$	0.00142		$N/74.48$	0.000729

} at 30°

TABLE VIII

*Reaction rate with diff. conc. of camphor.*Conc. of  $\text{Br}_2$  =  $N/37.24$ .

Medium	Conc. of camphor.	$k^{30^\circ}$ .	Medium	Conc. of camphor.	$k^{30^\circ}$ .
$\text{CCl}_4$	$M/20$	0.000864	$\text{CS}_2$	$M/40$	0.000083
	$M/40$	0.00686		$M/20$	0.000497
$\text{CS}_2$	$M/20$	0.00124	$\text{CHCl}_3$	$M/40$	0.000377

TABLE IX

*% Increase of  $k$  in diff. media with increase of conc. of acceptor molecules and with decrease of conc. of active molecules.*

Medium.	Dielec. const.	% Increase of $k^{30^\circ}$ when conc. of $\text{Br}_2$ is halved.	% Increase of $k^{30^\circ}$ when conc. of camphor is doubled.
$\text{CCl}_4$	2.25	14.29	25.95
$\text{C}_6\text{H}_6$	2.29	65.1	Not tried.
$\text{CS}_2$	2.61	83.8	49.4
$\text{CHCl}_3$	5.14	46.68 (30°)	31.84

## DISCUSSION

From Tables I to IV, the reaction is found to follow the unimolecular equation for a particular concentration of camphor and a particular concentration of  $\text{Br}_2$  in all the media. The results also indicate that there is no period of induction or photochemical after-effect. The reaction stops as soon as the light is cut off. Table VI shows that like many other reactions, the velocity constants of this reaction hold no direct relationship with the dielectric constants of the solvents. The temperature coefficients of the reactions also bear no direct relationship with the dielectric constants of the media.

Table VII shows the interesting peculiarity that the velocity constant increases as the concentration of  $\text{Br}_2$  is diminished. This peculiarity was also observed in a previous paper by the author (Mukherjee and Goswami, *J. Indian Chem. Soc.*, 1944, **21**, 237). Ghosh and Basu (*ibid.*, 1928, **5**, 343, 361) also observed this interesting peculiarity which apparently violated Maxwell's law,  $n'/n = \text{constant}$  at constant temperature, where  $n'$  = number of active molecules and  $n$  = total number of molecules. In order to explain this peculiarity Ghosh and Basu (*loc. cit.*) put forward an explanation that the presence of different amounts of oxygen in the reaction system was the cause of this abnormal change in the velocity constant. Oxygen acted like an inhibitor and in concentrated solution of  $\text{Br}_2$ , according to Ghosh and Basu, greater amount of  $\text{O}_2$  was present which explained the smaller velocity constant in more concentrated  $\text{Br}_2$  solution. According to them,  $\text{O}_2$  came from two sources :

- (i). Oxygen remaining dissolved in water used in experiments.
- (ii). Oxygen obtained from the dark reaction,  $\text{H}_2\text{O} + \text{Br}_2 = 2\text{HBr} + \text{O}$ .

In view of the fact, that such increase in velocity constants is also observed in non-aqueous solvents, as shown in Table VII, the applicability of similar explanation on the Oxygen theory in the present case is doubtful. The second source of oxygen is absent in non-aqueous solvents. Therefore it is doubtful that this increase is due to smaller amount of  $\text{O}_2$  in dilute solution of  $\text{Br}_2$ . The percentage of acceleration in the rate is greater in benzene than in others. The temperature coefficient in benzene is, however, smaller.

Table VIII shows that with the increase in the concentration of camphor molecules, the rate of the reaction increases as expected. The percentage of increase in the velocity constants with increase in the concentration of the camphor molecules or decrease in the concentration of  $\text{Br}_2$  molecules is not uniform in all media as shown in Table IX. The nature of solvents, hence, plays some part here too.

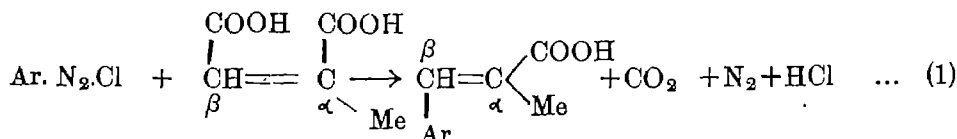
The author expresses his sincere thanks to Prof. J. L. Mukherjee, for his kind advice, encouragement and help. The author also thanks Prof. I. B. Sarkar for the facilities offered in the laboratory to carry out this piece of work.

# CONDENSATIONS OF ARYL DIAZONIUM SALTS WITH REACTIVE UNSATURATED COMPOUNDS. PART II. ACTION OF ARYL DIAZONIUM CHLORIDES WITH MALEIC ACID

BY JASWANT RAI AND KUNJ BEHARI LAL MATHUR

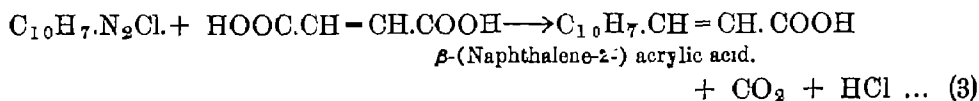
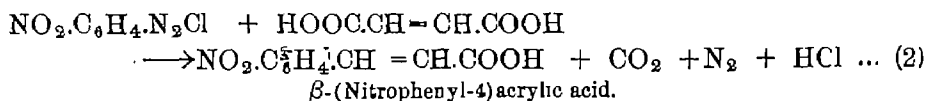
Aryl diazonium chlorides containing a negative substituent can react with maleic acid in the presence of copper chloride and sodium acetate to give  $\beta$ -aryl acrylic acids. Contrary to expectation, the use of acetone as a solvent is found to be unnecessary in these reactions. The latter affords a method for the synthesis of certain negatively substituted cinnamic acids directly.

Dhingra and Mathur (*J Indian Chem. Soc.*, 1947, 24, 123) extended the reactions of aryl diazonium chlorides with unsaturated carbonyl compounds (cf. Meerwein, Buchner and Emster, *J. prakt. Chem.*, 1939, ii, 152, 237; Koelsch, *J. Amer. Chem. Soc.*, 1943, 65, 57; Koelsch and Boekelheide, *ibid*, 1944, 66, 412) to an unsymmetrical compound containing two activating groups e.g., citraconic acid, and found that  $\beta$ -arylation occurred, the product in every case being  $\alpha$ -methylcinnamic acids formed thus,



This mode of aryl coupling lends support to the free radical mechanism advanced for such reactions by Koelsch *et al.* (*loc. cit.*). In the light of the above reactions it will be of interest to ascertain if cinnamic acids could be synthesised by using maleic acid. With this object in view a systematic study has been made of the reactions of aryl diazonium chlorides with maleic acid.

The presence of acetone and cupric chloride (0.005*M*), and the maintenance of a proper  $p_{\text{H}}$  are recognised as favourable conditions for successful coupling (cf. Meerwein *et al.*, *loc. cit.*, Koelsch *et al.*, *loc. cit.*). In fact, acetone is said to have a specific effect on the reactions. *p*-Nitrobenzene diazonium chloride and  $\beta$ -naphthalene diazonium chloride, when reacted with maleic acid under these conditions (vide experimental), afford the expected  $\beta$ -aryl acrylic acids, but in poor yield.



When, however, the above coupling reactions are repeated without acetone, the yields of the acids in (2) and (3) are improved considerably. Similar results are obtained with *o*-, and *m*-nitrobenzene diazonium chlorides. These experiments and others (*vide infra*) clearly demonstrate that the use of acetone is not essential in these reactions, rather its presence lowers the yield of the desired acids, presumably due to the formation of chloroacetone by a side reaction (cf. Meerwein, *loc. cit.*).

That these coupling reactions run the course as indicated in equations (2) and (3) is shown by the liberation of carbon dioxide, by the properties of the acids, and in most cases by the determination of their equivalent weights. In the case of the nitro-acids, comparison with authentic preparations of *o*-, *m*-, and *p*-nitrocinnamic acids by Perkin's reaction affords further confirmation as to the nature of these products.

Maintaining the usual conditions as regards the catalyst and the  $p_H$ , but omitting acetone, it is thus seen that representative class of mono- and di-negatively substituted amines can undergo the coupling reactions after diazotisation. The cinnamic acids obtained demand little further purification and in most cases they have been obtained in workable amounts. A practical advantage that accrues by this modification lies in conducting these reactions in aqueous solutions and even in solutions more dilute than usual cases. On these accounts, and due to ready availability of maleic acid, these syntheses are useful for the preparation of cinnamic acids.

The yields of the acids are adversely affected if the amount of sodium acetate used is less or more than the equivalent of available hydrochloric acid or it is replaced by pyridine. The poor yields are also obtained if the temperature is below 20° and excessive amounts of haloid ions are present in the reaction mixture.

The yield of *o*-nitrocinnamic acid, obtained as above, appears to be strikingly poor when compared with the yields of other cinnamic acids. The low yield cannot be ascribed to steric hindrance of the nitro group in the *ortho* position in the *o*-nitrobenzene diazonium chloride, as the yields of the halogen acids from *o*-chloro-, *o*-bromo- and *o*-iodo-benzene diazonium chlorides do not fall off progressively from the chloro to the iodo compound, i.e., even when the bulkiest iodine group is reached. Reactions with 2 : 6-dichloro-, and 2 : 4-dinitrobenzene diazonium chlorides suggest that the presence of an additional negative group in mono-negatively substituted diazonium chloride does not augment the yield of the cinnamic acid. In all such cases, where poor yields are obtained, more of the tarry matter is found to be present in the reaction mixture. The low yields are likely due to the highly negative nature of the parent amines, which in  $p_H$  range of 3 to 5 give easily decomposable *syn*-diazo forms and at higher  $p_H$  pass over to the inactive *anti*-diazotate (cf. Saunders, "The Aromatic Diazo Compounds and their Technical Applications", Edward Arnold Co., London, 1936, pp. 72-73).

Aniline and those amines, which contain a positive substituent in the nucleus, are found to give diazonium chlorides which resist all attempts to coupling with maleic acid either in the presence or absence of acetone. Such amines are, however, known to react with unsaturated aliphatic esters or nitriles (Koelsch, *loc. cit.*), though in poor yield. Attempts to condense benzene diazonium chloride as its mercury chloride double compound met with partial success, yielding only 6% of the cinnamic acid.

### EXPERIMENTAL

3-Nitro-4-methylaniline, *m*-chloro-, *m*-bromo- and *o*-bromoanilines were prepared in the laboratory. The rest of the amines and the maleic acid were from stock and were of requisite chemical purity.

For the determination of the equivalent weight of the acids, the sample (0.1-0.2 g.) was first dissolved in a known excess (10 c. c.) of *N*/5-caustic soda solution. Subsequently the alkali was neutralised by adding just 10 c.c. of *N*/5-sulphuric acid. In this way the acid was reprecipitated in a very fine hydrated form which could be titrated better than the crystalline sample taken in alcohol, with alkali (*N*/25) to the pink colour with phenolphthalein as indicator. The method was checked with an authentic sample of *p*-nitrocinnamic acid.

The *o*-, *m*- and *p*-nitrocinnamic acids were synthesised for comparison by heating the corresponding nitrobenzaldehydes (1.1 g. each) with powdered anhydrous sodium acetate (0.5 g) and acetic anhydride (3 c.c.) at 180° for 8 hours.

*Condensations of p-Nitrobenzene and β-Naphthalene Diazonium Chlorides with Maleic Acid, Copper Chloride and Sodium Acetate, with and without Acetone.*—*p*-Nitroaniline (0.025*M*, 3.45 g.) was dissolved by warming in hydrochloric acid (conc., 6 c.c., 2.5 times the base) diluted with water (9-12 c.c.). The solution was slightly cooled and the base hydrochloride precipitated by the addition of crushed ice (3-4 g.) and accompanied by external cooling with ice. To it was added an ice-cold solution of sodium nitrite (2.5 g., 68% pure) in water (7 c.c.) all at once, and the mixture thoroughly stirred for 10 minutes. In this way practically the whole of the amine was diazotised. The diazo solution was filtered and added to a solution containing maleic acid (0.025*M*, 2.9 g.), acetone (10 c. c.), copper chloride (1 g.) in water and sodium acetate (5.75 g.) in water (10 c. c.). The mixture was stirred throughout and the temperature was maintained at 30-40°. There was brisk effervescence for nearly one hour and it continued slowly for another 2 to 3 hours when a brownish solid deposited. The supernatant liquid was decanted off and the residue washed with a little water. It was then extracted with warm 5% aqueous sodium bicarbonate. The extract was acidified with dilute hydrochloric acid. An acid was precipitated (0.2 g.) which, after trituration with benzene, was crystallised from ethyl alcohol in needles, m.p. 282-84° (mixed m.p. with an authentic sample of *p*-nitrocinnamic acid). It decolorised 1% aqueous potassium permanganate and bromine water in the cold.



A similar experiment with  $\beta$ -naphthalene diazonium chloride gave only a trace of an unsaturated acid.

The experiment with *p*-nitrobenzene diazonium chloride with 1/50th the quantities in a Lunge's nitrometer, filled with mercury, showed small amount of carbon dioxide in the gas phase, indicating side reactions. The volume of nitrogen (11.6 c. c. at N. T. P.), however, corresponded with the amount of the diazonium chloride used.

When the condensations with *p*-nitro-, and  $\beta$ -naphthalene diazonium chlorides with maleic acid were repeated without using acetone, but keeping the bulk with water to 40 c. c., the yields of the unsaturated acids were as follows :—

	Amount.	M. p.
<i>p</i> -Nitro derivative	2.8 g.	282-83°
$\beta$ -Naphthalene „	0.4	192-94°

*Condensations of various Aryl Diazonium Chlorides with Maleic  
Acid in the presence of Copper Chloride and Sodium Acetate,  
but without Acetone*

The amines (0.025 *M*) were diazotised in the same manner as with the nitroaniline and the filtered solutions (20 c. c.) were added to maleic acid (0.025 *M*) in the presence of copper chloride (1 g.) and sodium acetate (5.75 g.). The total volume of the reaction mixture was adjusted with water to 45 c. c. The temperature was maintained within 30 to 40°. The effervescence was more or less vigorous for  $\frac{1}{2}$  to  $\frac{3}{4}$  hour and then continued for another 2 to 3 hours. From the reaction products, the acids were extracted out with warm aqueous sodium bicarbonate, leaving behind the neutral matter, tar etc. More tar was present in experiments with *o*-nitro-, 2 : 6-dichloro- and 2 : 4-dinitro-benzene diazonium chlorides. From the extracts, the unsaturated acids were precipitated out in sufficiently pure conditions after acidification. The acids could be recrystallised from alcohol or dilute alcohol. Trituration of the precipitated acid with benzene was only resorted to in the case of the nitro-acid.

In the diazotisation of the naphthylamines, considerable insoluble undiazotised matter was left behind. 2 : 4-Dinitrobenzene diazonium chloride was obtained indirectly. 2 : 4-Dinitroaniline (*M*/80, 2.38 g.) was diazotised (cf. Groggins, "Unit Processes in Organic Synthesis", Mc Graw-Hill Book Company, Inc., London, 1938, p. 134) by nitrosylsulphuric acid with sodium nitrite (1.25 g.) and sulphuric acid (conc., 6 c. c.). The filtered diazonium sulphate was treated with a paste made of barium chloride (32 g.). There was a lowering in temperature accompanied by evolution of hydrogen chloride. The mixture was filtered from the precipitated barium sulphate. Sodium acetate (33 g.) was then added, as in other cases, equivalent to the available hydrogen chloride.

The results with the various diazotised amines, including those of the *p*-nitro and  $\beta$ -naphthalene derivatives (*vide supra*) are summarised in Table I,

below. The mixed melting points recorded are those of the acids from the diazotised nitroanilines, admixed with an authentic sample of the expected nitro-cinnamic acid (vide p. 386). Where there are mentioned more than one melting point in literature, only that which corresponds to the experimental value has been cited.

TABLE I

Amine (diazotised) & wt.	Amount of acid.	Yield	M.p of the pure acids.		Ar.CH : CH.CO <sub>2</sub> H equiv.		Re- mark.
			Found.	Lit.	Found.	Calc.	
<i>p</i> -Nitroaniline (3.45 g.)	2.8 g.	58%	282-84°	285° (Alway & Bonner, <i>Amer. Chem. J.</i> , 1904, 32, 392)	195	193	Mixed m. p. 283-85°.
$\beta$ -Naphthylamine (3.60 g.)	0.4	8	192-94°	196° (Rousset, <i>Bull. soc. chim.</i> , 1897, 17, 815.)	201	198	...
<i>m</i> -Nitroaniline (3.45 g.)	1.2	24	195-96°	196° (Schiff, <i>Ber.</i> , 1878, 11, 1782)	193	193	Mixed m p. 195-96°
<i>a</i> -Nitroaniline (3.45 g.)	0.35	7.3	236-37°	239-40° (Gabriel & Meyer, <i>Ber.</i> , 1881, 14, 830)	197	193	Mixed m.p. 238-40°
<i>p</i> -Chloroaniline (3.2 g.)	1.3	23.5	240-41°	240-42° (Gabriel & Herz- berg, <i>Ber.</i> , 1883, 16, 2039)	187	182.5	...
<i>p</i> -Bromoaniline (4.3 g.)	1.62	23.6	*248-51°	Sinters at 248° and m.p. 251-53° (Gabriel, <i>Ber.</i> , 1882, 15, 2301)	232	227	...
<i>m</i> -Chloroaniline (3.2 g.)	1.30	23.5	*174-75°	176° (Gabriel & Herzberg, <i>Ber.</i> , 1883, 16, 2039)	186	182.5	...
<i>m</i> -Bromoaniline (4.3 g.)	1.5	26.5	176-77°	176-77° (Miller & Rohde, <i>Ber.</i> , 1890, 23, 1890)	234	227	...
<i>o</i> -Chloroaniline (3.2 g.)	1.25	27.5	198-99°	198-99° (Gabriel & Herz- berg, <i>Ber.</i> , 1883, 16, 2036)	180	182.5	...
<i>o</i> -Bromoaniline (4.3 g.)	1.3	23.2	211-12°	212-12.5° (Gabriel, <i>Ber.</i> , 1882, 15, 2295)	234	227	...
<i>o</i> -Iodoaniline (2.7 g.)	0.8	23.3	212-13°	212-14° (Gabriel & Herzberg, <i>Ber.</i> , 1883, 16, 2037)	...	...	With M/80 amount
4-Methyl-3-nitro- aniline (3.8 g.)	0.7	13.5	170-71°	170-71° (Hanzlik, <i>Ber.</i> , 1899, 32, 2285)	212	207	...
2 : 6-Dichloro- aniline (4.0 g.)	1.1	20.8	182-83°	184° (Reich, <i>Bull. soc. chim.</i> , 1917, <i>iv</i> , 21, 218-221)	220	217	...
2 : 4-Dinitro- aniline (2.3 g.)	0.45	7.3	175-78°	179° (Friedlander, <i>Monatsh.</i> , 1881, 23, 535)	...	...	With M/80 amount
$\alpha$ -Naphthylamine (3.2 g.)	0.35	7.0	205-07°	205° (Rousset, <i>Bull. soc. chim.</i> , 1897, <i>iii</i> , 17, 813).	...	...	...

\* From dilute alcohol.

Experiments repeated with *m*-, and *p*-nitrobenzene diazonium chlorides and  $\beta$ -naphthalene diazonium chloride in a total bulk of 120 c. c. gave identical results. Similarly variation in the amount of copper chloride (0.5 to 6 g.) had little effect on the yields. The yields were adversely affected when in experiments e.g., with *o*-, *m*-, and *p*-nitrobenzene diazonium chlorides, 3 g. or 10g. of sodium acetate were used. Similarly the use of pyridine (5 c. c.) in place of sodium acetate e.g., in experiments with *p*-nitro-, *p*-chloro-, *p*-bromo-, *m*-nitro-, *m*-chloro- benzene diazonium chlorides and  $\beta$ -naphthalene diazonium chloride, gave lower yields of the acids. In the experiment with the *o*-chlorobenzene diazonium chloride the use of potassium chloride (7.45 g.), potassium bromide (11.9 g.) or potassium iodide (16.6 g.) in amounts four times ( $M/10$ ) the equivalent of the base, lessened the yields of the acid but increased the amount of the neutral product. No acid was obtained from diazotised aniline, *o*-xylydine, *o*- and *p*-anisidines, *p*-amino-acetanilide with or without acetone. The compound, probably  $C_6H_5 \cdot N_2 \cdot Cl \cdot HgCl_2 \cdot H_2O$ , ( $M/40$ , 10 g.), prepared in the way of the antimony compound (cf. May, *J Chem. Soc.* 1912, 101, 1037) when heated at 120° with maleic acid ( $M/40$ , 2.9 g.) in glacial acetic acid (15 c. c.) gave in the presence of copper chloride (1 g.) and sodium acetate (5.75 g.) only 0.2 g. of cinnamic acid (i.e., 6% of the theory).

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# STUDIES IN THE NEGATIVELY CHARGED COLLOIDAL SOLUTIONS OF VARIOUS FERRIC SALTS. PART. V. NEGATIVELY CHARGED FERRIC ARSENATE SOL

BY S. P. MUSHRAN AND SATYA PRAKASH

This paper presents an investigation on the preparation and properties of the negatively charged colloidal solutions of ferric arsenate. The sols were prepared by dispersing freshly precipitated ferric arsenate by caustic soda in presence of glucose or glycerine. The composition of the sol peptised in presence of glucose is  $11\text{Fe}_2\text{O}_3 \cdot 2\text{FeAsO}_4 \cdot 8\text{H}_2\text{O}$ , and that of the sol peptised in presence of glycerine is  $9\text{Fe}_2\text{O}_3 \cdot 2\text{FeAsO}_4 \cdot 3.5\text{H}_2\text{O}$ . Various other characteristics of the sols have also been investigated.

Grimaux (*Compt. rend.*, 1884, 98, 1540) obtained the positively charged sol of ferric arsenate by the dialysis of a mixture of ferric chloride in excess and potassium arsenate. Holmes and Arnold (*J. Amer. Chem. Soc.*, 1918, 40, 1014) showed that freshly precipitated ferric arsenate could also be peptised by ferric sulphate and ferric nitrate. Prakash and Dhar (*J. Indian Chem. Soc.*, 1929, 6, 587) studied various aspects of the formation of ferric arsenate jelly and Prakash and Dube (*Z. anorg. Chem.*, 1932, 208, 163) studied the kinetics of the sol-gel transformation of this jelly. As no attempt appears to have been made to prepare and to study the negatively charged colloidal solution of ferric arsenate, this investigation was taken up in this laboratory. In this paper the experimental results on the compositions and various properties of such negatively charged sols of ferric arsenate have been reported. An idea of the peptisation of ferric arsenate by caustic soda in presence of glucose or glycerine can be had from the following figures.

1.0-2.0 C. c. of ferric chloride solution (30.36 g. of ferric oxide per litre), when mixed with 1.0 to 3.0 c.c. of 20% potassium dihydrogen arsenate solution in presence of 0.1 to 3.0 c. c. of 20% glucose solution, requires 2.8 to 5.0 c. c. of 0.5N-NaOH solution (total volume 10 c. c.) to bring about complete peptisation in half an hour.

1.0-2.0 C. c. of the ferric chloride solution, when mixed with 1.0 to 3.0 c. c. of the potassium dihydrogen arsenate solution in presence of 1.0 to 3.0 c. c. of glycerine, requires 2.6 to 5.0 c. c. of 0.5N-NaOH solution (total volume 10 c. c.) to bring about complete peptisation in half an hour.

## EXPERIMENTAL

Sol A was prepared by mixing 40 c. c. of ferric chloride solution (30.36 g. of ferric oxide per litre), 40 c. c. of 20% potassium dihydrogen arsenate solution, 20 c. c. of 20% glucose solution and 100 c. c. of 0.5N-NaOH solution. The total volume was kept at 200 c. c. The sol was dialysed for 15 days.

Sol B was prepared by mixing 40 c. c. of the same  $\text{FeCl}_3$  solution,  $\text{KH}_2\text{AsO}_4$  solution (40 c. c.), glycerine (20 c. c.) and 0.5N-NaOH solution (100 c. c.). The total volume was kept at 200 c. c. and the sol was dialysed for 15 days.

*Composition of the Sols*

The amount of iron in a known volume of the sol was estimated by the use of the reagent cupferron (Mushran and Prakash, *J. Indian Chem. Soc.*, 1946, 23, 413). The total arsenate was estimated as  $\text{As}_2\text{S}_3$  (Bunsen's method). In order to ascertain the amount of the arsenate in combined state with iron, a known volume of the sol was coagulated by potassium chloride, the total coagulum was collected, washed and estimated as  $\text{As}_2\text{S}_3$ . The coagula were also obtained cataphoretically and estimated for arsenate; the concordance of the results showed that the equilibrium between the free and the combined arsenate was not appreciably altered during these processes. The combined iron corresponding to this amount of arsenate was calculated on the assumption that the ferric arsenate was  $\text{FeAsO}_4$ . The rest of the iron was present as hydrated ferric oxide. From the ratio of the free to the combined iron, the empirical formula of the sol was calculated. The viscosity of the sol was measured by the Ostwald's method at  $30^\circ$  and the amount of bound water was calculated from the Hatschek's equation (vide Part I of this series, *J. Indian Chem. Soc.*, 1946, 23, 111).

TABLE I

	Sol A	Sol B		Sol A	Sol B
Per litre.	Glucose sol.	Glycerine sol.	Per litre.	Glucose sol.	Glycerine sol.
Total iron	0.9604 g.	0.9092 g.	Free iron	0.8804 g.	0.8198 g.
Total arsenate (As)	0.2132	0.2306	Viscosity of sol	0.00840	0.00834
Combined arsenate (As)	0.1073	0.1200	Viscosity of water	0.00803	0.00808
Free arsenate (As)	0.1059	0.1106	Bound water	0.0854	0.0514
Combined iron	0.0800	0.0894	Empirical formula	$11\text{Fe}_2\text{O}_3 \cdot 2\text{FeAsO}_4 \cdot 6\text{H}_2\text{O}$ $9\text{Fe}_2\text{O}_3 \cdot 2\text{FeAsO}_4 \cdot 8.5\text{H}_2\text{O}$	

The sols were coagulated cataphoretically as well as by  $0.5N$ -KCl, centrifuged and the hydrogen-ion concentrations of the supernatant aqueous layers were determined by the Hildebrand's hydrogen electrode. The following  $pH$  values were recorded.

	Glucose sol (A).	Glycerine sol (B).
$pH$	7.04 (KCl coagulated)	7.02 (KCl coagulated)
	7.05 (cataphoretically coagulated)	7.06 (cataphoretically coagulated)

*Conductivities of the Sols*

In Table II are recorded the conductivities of these sols as affected by (a) dilution, (b) ageing, and (c) temperature.

TABLE II A

*Conductivity values at dilutions (30°).*

Dilutions	Conductivity of		Dilutions.	Conductivity of	
	sol A.	sol B		sol A.	sol B
Original sol (X)	$1.10 \times 10^{-4}$ mho	$2.06 \times 10^{-4}$ mho	X/2	$0.60 \times 10^{-4}$ mho	$1.05 \times 10^{-4}$ mho
5X/6	0.98	1.73	X/3	0.40	0.72
2X/3	0.75	1.40	X/6	0.23	0.40

TABLE II B

*Conductivity values on ageing (30°).*

Date.	Conductivity of		Date	Conductivity of	
	sol A.	sol B.		sol A.	sol B.
25.11.45	$1.10 \times 10^{-4}$ mho	$2.06 \times 10^{-4}$ mho	26.4.46	$1.22 \times 10^{-4}$ mho	$2.14 \times 10^{-4}$ mho
20.12.45	1.14	2.08	10.5.46	1.24	2.15
20. 2.46	1.19	2.11	19.7.46	1.26	2.17

TABLE II C

*Conductivity values at diff. temps.*

Temp.	Glucose sol (A).		Glycerine sol (B).	
	Conducty.	Diff. per 5°.	Conducty.	Diff per 5°.
47°	$1.30 \times 10^{-4}$ mho		$2.35 \times 10^{-4}$ mho	
35°	1.20	0.10	2.18	0.17
30°	1.10	0.10	2.00	0.18
25°	0.99	0.11	1.82	0.18
20°	0.89	0.10	1.63	0.19
15°	0.81	0.09	1.45	0.18
Temp. of zero conductance (extrapolated)		-20.25°		-20.60°
Temp. coefficient per 1°	...	0.020		0.036

The above data indicate that the sols are pretty stable on dilution, as the conductivities of the sols are very nearly proportional to the dilutions. The conductivities of the sols increase with age. The conductivity-temperature curves are straight lines. The temperature of zero conductance of the sols range between -20.25° and -20.60°.

It will be of interest to study the temperature coefficients of the sols. The temperature coefficients per 1° along with the conductivities at 35° are given below.

	Conductivity at 35°.	Temp. coeff. per 1°.
Sol A	$1.20 \times 10^{-4}$ mho	0.020
Sol B	2.18	0.036

The temperature coefficient of sol A is thus 1.66% of the conductance at 35° and that of sol B is 1.65% of the conductance at 35°.

*Extinction Coefficients of the Sols*

Extinction coefficients of the sols were determined by the Nutting's spectrophotometer, at different dilutions and at different wave-lengths and the results are recorded in Table III (X stands for the original undiluted sol).

TABLE III

Wave-lengths.	Sol A. Dilutions				Sol B. Dilutions			
	X.	X/2.	X/4.	X/8.	X.	X/2.	X/4.	X/8.
4800 $\text{\AA}$	2.40	1.21	0.61	0.31	1.38	0.67	0.34	0.17
4900	1.80	1.00	0.51	0.25	1.10	0.56	0.29	0.15
5000	1.60	0.81	0.41	0.20	0.98	0.50	0.26	0.13
5200	1.10	0.56	0.28	0.14	0.62	0.32	0.16	0.08
5400	0.76	0.38	0.20	0.10	0.45	0.23	0.12	0.06
5600	0.44	0.23	0.12	0.06	0.30	0.16	0.09	0.05
5800	0.33	0.17	0.09	0.05	0.21	0.11	0.06	0.03
6000	0.22	0.12	0.06	0.03	0.15	0.08	0.04	0.02

The above results show that the sols rigidly obey Beer's law i.e., the extinction coefficients are almost proportional to the dilutions. This suggests that the sols are quite stable and do not hydrolyse during the process of dilution. Our results on the conductivities of the sols at different dilutions (Table IIa) also show similar behaviour.

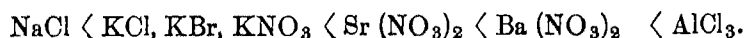
*Coagulation of the Sols*

In Table IV are recorded the minimum amounts of electrolytes necessary to coagulate 1 c. c. of the sols in a total volume of 10 c. c., the time allowed in each case being 30 minutes.

TABLE IV

Electrolytes.	Amount necessary to coagulate		Electrolytes.	Amount necessary to coagulate	
	sol A.	sol B.		sol A.	sol B.
0.5 N-NaCl	0.50 c. c.	1.20	0.004 N-Ba (NO <sub>3</sub> ) <sub>2</sub>	0.60 c. c.	1.10 c. c.
0.5 N-KCl	0.30	0.90	0.004 N-Sr (NO <sub>3</sub> ) <sub>2</sub>	0.70	1.80
0.5 N-KNO <sub>3</sub>	0.30	0.90	0.004 N-AlCl <sub>3</sub>	0.20	0.40
0.5 N-KBr	0.30	0.90			

The coagulating powers of the ions thus fall in the following series :



The effect of dilution on the coagulation values has also been investigated and the results are recorded in Table V (total volume was 10 c. c.).

TABLE V

Electrolytes.	Amount necessary to coagulate (c. c.)					
	glucose sol (A)			glycerine sol (B)		
	1 c. c.	2 c. c.	3 c. c.	1 c. c.	2 c. c.	3 c. c.
0.5 <i>N</i> -NaCl	0.50	0.60	0.70	1.20	1.30	1.40
0.5 <i>N</i> -KCl	0.80	0.40	0.50	0.90	1.00	1.10
0.5 <i>N</i> -KNO <sub>3</sub>	0.80	0.40	0.50	0.90	1.00	1.10

From this table it is evident that the sols obey the Schulze-Hardy rule for the coagulation with electrolytes and that they show the normal behaviour with dilution.

#### *Positively Charged Ferric Arsenate Sols*

In Table VI are recorded the compositions of some positively charged sols that we have prepared.

Sol A was prepared by dialysing a mixture of 40 c. c. of ferric chloride solution (69.84 g. of Fe<sub>2</sub>O<sub>3</sub> per litre) and 15 c. c. of 20% potassium dihydrogen arsenate solution for 3 days.

Sol B was prepared by dialysing a mixture of 40 c. c. of ferric chloride solution (of the same strength) and 25 c. c. of 20% potassium dihydrogen arsenate solution for 4 days.

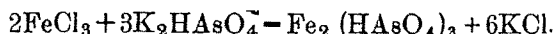
TABLE VI

Per litre.	Sol A.	Sol B.
Total iron	11.8478 g	17.4151 g.
Combined arsenate (As)	7.1320	13.8582
Combined iron	5.3128	10.3234
Free iron	6.5350	7.0917
Viscosity of sol (30°)	0.00900	0.00928
Bound water	1.2520	2.4440
Empirical formula	3Fe <sub>2</sub> O <sub>3</sub> .5FeAsO <sub>4</sub> .4H <sub>2</sub> O.	Fe <sub>2</sub> O <sub>3</sub> .3FeAsO <sub>4</sub> .2H <sub>2</sub> O.
Chloride ions per litre	8.4220 g.	3.3190 g.

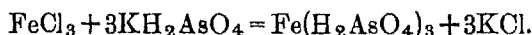


## DISCUSSION

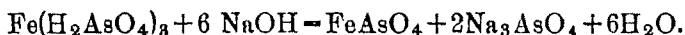
According to Pfaff (*Akad. Handl. Stockholm*, 1818, 22, 255) a solution of ferric chloride gives a white precipitate when treated with disodium hydrogen arsenate. Various investigators have analysed this precipitate. The analysis given by Berzelius (*ibid.*, 1824, 28, 354) corresponds to ferric monohydrogen arsenate,  $\text{Fe}_2(\text{HAsO}_4) \cdot 4.5\text{H}_2\text{O}$ . Metzke (*Z. anorg. Chem.*, 1910, 32, 626) obtained ferric dihydrogen arsenate,  $\text{Fe}(\text{H}_2\text{AsO}_4) \cdot 5\text{H}_2\text{O}$ , by dissolving artificial pharmacosiderite in syrupy arsenic acid and heating this solution. Usually when a dipotassium arsenate solution is added to an excess of ferric chloride, the substance precipitated is monohydrogen arsenate according to the following equation :



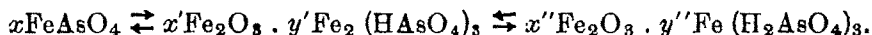
When the precipitation is carried out by potassium dihydrogen arsenate, the precipitate obtained is very likely ferric dihydrogen arsenate :



This is the expected composition of the positively charged ferric arsenate sol obtained by peptising the ferric dihydrogen arsenate with ferric chloride. But in the case of negatively charged sols, which are prepared in presence of excess of alkali, the constitution probably corresponds to ferric *ortho*arsenate,  $\text{FeAsO}_4$  :

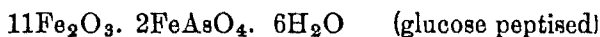


In the course of dialysis, most of the sodium arsenate, thus formed, is eliminated, but the sol still contains a considerable amount of ferric arsenate. A portion of ferric arsenate is also hydrolysed during the course of dialysis and the following equilibria are ultimately maintained :



The compositions of the negatively and positively charged ferric arsenate sols are given below. For comparison, positively charged ferric arsenate sols have also been expressed in terms of  $\text{FeAsO}_4$  (though it is very likely that the actual composition corresponds to dihydrogen arsenate).

Negatively charged :



Positively charged :



It is thus clear that the positively charged ferric arsenate sols contain a larger content of arsenate combined with iron than the negatively charged sols.

We have studied in details the various characteristics of the negatively charged sols and from the results recorded in the foregoing tables, the following observations may be summarised :

1. The electrical conductivities of the sols are proportionate to the dilutions.
2. The electrical conductivities of the sols are linear functions of temperatures of zero conductance. Temperature of zero conductance lies between  $-20.25^{\circ}$  and  $-20.60^{\circ}$ .
3. The temperature coefficients of conductivity per  $1^{\circ}$  of the sols are always less than 2% of the conductances at  $35^{\circ}$ .
4. With ageing, the conductivities of the sols increase.
5. Measurements of extinction coefficients show that the sols obey Beer's law.
6. The  $pH$  values of the dispersion medium lie between 7.02 and 7.06 showing that the sols are slightly basic owing to the stabilising hydroxide ions.
7. The sols obey the Schulze-Hardy rule for the coagulation with electrolytes. They show the normal behaviour with dilution.

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# STUDIES IN THE NEGATIVELY CHARGED COLLOIDAL SOLUTIONS OF VARIOUS FERRIC SALTS. PART VI. NEGATIVELY CHARGED FERRIC PHOSPHATE SOL

BY S. P. MUSHRAN

Negatively charged ferric phosphate sols have been prepared and studied. The sols were prepared by adding potassium dihydrogen phosphate solution to ferric chloride solution and dispersing the precipitate of ferric phosphate by caustic soda in presence of glucose or glycerine. The glucose-peptised sol has the composition  $8\text{Fe}_2\text{O}_3 \cdot 2\text{FePO}_4 \cdot 3\text{H}_2\text{O}$  and the glycerine-peptised sol,  $5\text{Fe}_2\text{O}_3 \cdot 2\text{FePO}_4 \cdot 11\text{H}_2\text{O}$ . Various other characteristics of the sols have been investigated.

The study of the positively charged sols and gels of ferric phosphate has attracted the attention of numerous workers. Holmes and co-workers (*J. Amer. Chem. Soc.*, 1916, 38, 1970; 1918, 40, 1014) have observed that freshly precipitated ferric phosphate can be peptised by methylamine, aqueous ammonia, ferric chloride or sulphate and nitric or hydrochloric acid. Varma and Parkash (*Z. anorg. Chem.*, 1932, 205, 241) investigated the peptisation of ferric phosphate by ferric chloride in presence of various peptising agents such as glucose, glycerine and urea; Prakash and Dhar (*J. Indian Chem. Soc.*, 1929, 6, 391; 1930, 7, 417) studied changes in the viscosity of the sol during setting to a jelly. The rhythmic precipitation of the hydrogel was investigated by Chatterji and Dhar (*Kolloid Z.*, 1926, 40, 98) and Banerji and Ghosh (*ibid.*, 1933, 65, 37) determined the viscosities of the sol at various pressures. The kinetics of sol-gel transformation of ferric phosphate was investigated by Dube and Prakash (*Z. anorg. Chem.*, 1934, 217, 284). Prakash (*Indian J. Phys.*, 1933, 8, 243) found no marked change in the magnetic susceptibility of ferric phosphate sol when it was converted into a gel. The sols and gels of ferric phosphate, studied so far, are positively charged and no attempt seems to have been made to prepare and investigate the negatively charged sols of ferric phosphate. Sëll (*Proc. Camb. Phil. Soc.*, 1904, 12, 388) mentions the formation of a negatively charged brownish red sol, obtained by dissolving ferric phosphate in diammonium hydrogen phosphate in presence of ammonia.

In a recent publication, Mushran (*Curr. Sci.*, 1946, 15, 224) has observed that if an excess of potassium dihydrogen phosphate solution is added to a ferric chloride solution, a permanent precipitate of ferric phosphate is obtained, which can be easily dispersed by caustic soda to give a bright red sol of ferric phosphate which bears a negative charge, as shown by the cataphoretic method. The peptisation is greatly facilitated by the addition of glucose or glycerine. In previous communications of this series, Mushran and Prakash (*J. Indian Chem. Soc.*, 1946, 23, 111, 391, 413, 446) have described the negatively charged colloidal solutions of various ferric

salts. In this paper observations have been made regarding the compositions and properties of the negatively charged ferric phosphate sols. An idea of the peptisation of ferric phosphate by caustic soda in presence of glycerine or glucose can be had from the following figures :

1.0-2.0 C.c. of a ferric chloride solution (30.36 of  $\text{Fe}_2\text{O}_3$  per litre), when mixed with 1.0 to 3.0 c.c. of a 10% potassium dihydrogen phosphate solution in presence of 1.0 to 3.0 c.c. of 20% glucose solution, requires 2.8 to 4.2 c.c. of *N*-NaOH solution (total volume 10 c.c.) to bring about complete peptisation in half an hour.

1.0-2.0 C.c. of the same ferric chloride solution, when mixed with 1.0 to 3.0 c.c. of the potassium dihydrogen phosphate solution in presence of 1.0 to 3.0 c.c. of glycerine, requires 2.0 to 4 c.c. of *N*-NaOH solution (total volume 10 c.c.) to bring about complete peptisation in half an hour.

#### EXPERIMENTAL

Sol A was prepared by mixing 40 c.c. of a ferric chloride solution (30.36 g. of  $\text{Fe}_2\text{O}_3$  per litre), 40. c.c. of a 10% potassium dihydrogen phosphate solution and 20 c.c. of a 20% glucose solution and 84 c.c. of *N*-NaOH solution. The total volume was raised to 200 c.c. The sol was dialysed for 15 days.

Sol B was prepared by mixing 40 c.c. of the same ferric chloride solution, 40 c.c. of 10% potassium dihydrogen phosphate solution, 20 c.c. of glycerine and 80 c.c. of *N*-NaOH solution. The total volume was raised to 200 c.c. The sol was dialysed for 15 days.

#### *Composition of the Sols*

The amounts of iron in a known volume of the sol was estimated by dissolving the sol in hydrochloric acid and reducing with stannous chloride, and the ferrous iron was titrated against potassium dichromate (vide Part I of this series, *J. Indian Chem. Soc.*, 1946, 23, 111).

The total phosphate in a known volume of the sol was estimated gravimetrically as ammonium phosphomolybdate.

To determine the amount of the phosphate in the combined state with iron, a known volume of the sol was cataphoretically coagulated, by taking the sol in a U-tube with platinum electrodes and passing a current when the sol was coagulated at the anode. The total coagulum was collected, washed and estimated for phosphate. The coagula were also obtained by the use of potassium chloride and the concordance of the results showed that the equilibrium between the free and the combined phosphate was not appreciably altered. The combined iron corresponding to this

amount of phosphate was calculated on the assumption that the ferric phosphate was  $\text{FePO}_4$ . The rest of the iron was present as hydrated ferric oxide. From the ratio of the free to the combined iron, the empirical formula of the sol was calculated. The viscosity of the sol was measured by the Ostwald's method at  $30^\circ$ , and the amount of bound water was calculated from the Hatschek's equation (vide Part I of this series, *loc. cit.*).

TABLE I

Per litre.	Sol A Glucose sol.	Sol B Glycerine sol
Total iron	1.1636g.	1.1724g.
Total phosphate ( $\text{PO}_4$ )	0.5430	0.5772
Combined phosphate ( $\text{PO}_4$ )	0.2280	0.3200
Free phosphate ( $\text{PO}_4$ )	0.3150	0.2572
Combined iron	0.1340	0.1860
Free iron	1.0296	0.9864
Viscosity of sol	0.00836	0.00664
Viscosity of water	0.00803	0.00803
Water, bound	0.06151	0.3519
Empirical formula	$8\text{Fe}_2\text{O}_3 \cdot 2\text{FePO}_4 \cdot 3\text{H}_2\text{O}$	$5\text{Fe}_2\text{O}_3 \cdot 2\text{FePO}_4 \cdot 11\text{H}_2\text{O}$

The sols were coagulated cataphoretically as well as by 0.1N-potassium chloride, centrifuged and the  $\text{H}^+$ -ion concentration of the supernatant aqueous layers was determined by Hildebrand's hydrogen electrode. The following pH values were recorded.

Sol A	Sol B
pH 7.03 (coagulated by KCl)	7.04 (coagulated by KCl)
7.20 (cataphoretically coagulated)	7.18 (cataphoretically coagulated)

### Conductivities of the Sols

In Table II are recorded the observations on the conductivities of these sols at various dilutions, at various temperatures, and also the values on ageing.

TABLE IIA

### Conductivity values at dilutions ( $30^\circ$ ).

Dilutions.	Conductivity of sol A.	Conductivity of sol B.	Dilutions.	Conductivity of sol A.	Conductivity of sol B.
Original sol (X)	$3.52 \times 10^{-4}$ mho	$2.60 \times 10^{-4}$ mho	X/2	$1.78 \times 10^{-4}$ mho	$1.40 \times 10^{-4}$ mho
5X/6	3.01	2.20	X/3	1.26	1.01
2X/3	2.37	1.72	X/6	0.61	0.48

TABLE IIb

*Conductivity values on ageing. (30°).*

Date.	Conductivity of		Date.	Conductivity of	
	sol A.	sol B.		sol A.	sol B.
18.9.45	$3.52 \times 10^{-4}$ mho	$2.60 \times 10^{-4}$ mho	21.12.45	$3.75 \times 10^{-4}$ mho	$2.70 \times 10^{-4}$ mho
20.10.45	3.58	2.68	2.3.46	4.00	2.84
20.11.45	3.65	2.67	4.4.46	4.02	2.85

TABLE IIc

*Conductivity values at diff. temperatures.*

Temp.	Glucose sol (A)		Glycerine sol (B)	
	Conducty.	Diff. per 5°.	Conducty.	Diff. per 5°.
40°	$4.17 \times 10^{-4}$ mho		$3.05 \times 10^{-4}$ mho	
		0.33		0.25
35°	3.84	0.32	$2.80 \times 10^{-4}$	0.20
30°	3.52	0.33	2.60	0.30
25°	3.19	0.33	2.30	0.25
20°	2.86		2.05	
Temp. of zero conductance (extrapolated)		-22.0°		-20.5°
Temp. coeff. per 1°		0.066		0.060

From the above data the sols appear to be pretty stable on dilution, as the conductivities of the sols are very nearly proportional to the dilutions. The conductivities of the sols increase with age. The temperatures of zero conductance range between -22.0° and -20.5°.

*Extinction Coefficients of the Sols*

Extinction coefficients of the sols were determined by the Nutting spectrophotometer at different dilutions and at different wave-lengths and the results are recorded in Table III (X stands for the original undiluted sol).

TABLE III

Wave-lengths.	Sol A				Sol B			
	Dilutions				Dilutions			
	X.	X/2.	X/4.	X/8.	X.	X/2.	X/4.	X/8.
5000Å	3.00	1.60	0.90	0.45	2.00	1.02	0.51	0.26
5200	2.50	1.28	0.65	0.33	1.60	0.82	0.42	0.21
5400	1.90	0.95	0.48	0.24	1.20	0.61	0.30	0.15
5600	1.40	0.72	0.36	0.18	0.85	0.43	0.22	0.11
5800	1.00	0.52	0.27	0.14	0.61	0.31	0.16	0.08
6000	0.72	0.36	0.18	0.10	0.45	0.23	0.12	0.06
6200	0.54	0.27	0.14	0.08	0.34	0.18	0.09	0.05
6400	0.46	0.24	0.12	0.07	0.30	0.15	0.07	0.04

From these data the sols appear to obey Beer's law i.e. the extinction coefficients are almost proportional to the dilutions. This suggests that the sols are quite stable and do not hydrolyse during the process of dilution. The results on the conductivities of the sols at different dilutions (Table II A) also show the similar behaviour.

### *Coagulation of the Sols*

In Table IV are recorded the minimum amounts of electrolytes necessary to coagulate 1 c.c. of the sols in a total volume of 10 c.c., the time allowed in each case being 30 minutes.

TABLE IV

Electrolytes.	Amount necessary to coagulate		Electrolytes.	Amount necessary to coagulate	
	sol A.	sol B.		sol A.	sol B.
0.1N-NaCl	1.40 c.c.	1.20 c.c.	0.005N-BaCl <sub>2</sub>	0.70 c.c.	0.60 c.c.
0.1N-KCl	1.20	1.00	0.005N-Sr(NO <sub>3</sub> ) <sub>2</sub>	0.80	0.80
0.1N-KNO <sub>3</sub>	1.20	1.00	0.004N-AlCl <sub>3</sub>	0.60	0.50
0.1N-KI	1.20	1.00			

The coagulating powers of the ions thus fall in the following series :  
 NaCl < KCl, KI, KNO<sub>3</sub> < Sr (NO<sub>3</sub>)<sub>2</sub> < BaCl<sub>2</sub> < AlCl<sub>3</sub>.

The effect of dilution on the coagulation values has also been investigated and the results are recorded in Table V.

TABLE V

Electrolytes	Amount necessary to coagulate (c.c.)					
	Sol A.			Sol B.		
	1 c.c.	2 c.c.	3 c.c.	1 c.c.	2 c.c.	3 c.c.
0.1N-NaCl	1.40	1.80	1.80	1.20	1.40	1.60
0.1N-KCl	1.20	1.30	1.40	1.00	1.10	1.20
0.1N-KNO <sub>3</sub>	1.20	1.30	1.40	1.00	1.10	1.20

From the above table it is evident that the sols obey the Schulze-Hardy rule for the coagulation with electrolytes. They show the normal behaviour with dilution

### *Positively Charged Ferric Phosphate Sols*

The sols were prepared by peptising freshly precipitated ferric phosphate in excess of ferric chloride. In Table VI are recorded the compositions of some

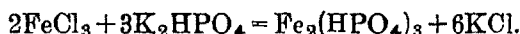
positively charged sols of ferric phosphate. Sol A was prepared by mixing 40 c.c. of a ferric chloride solution (69.84 g. of  $\text{Fe}_2\text{O}_3$  per litre) and 40 c.c. of 10%  $\text{KH}_2\text{PO}_4$  solution. The total volume was kept at 90 c.c. The sol was dialysed for 3 days. Sol B was prepared by mixing 40 c.c. of ferric chloride solution (of the same strength) and 30 c.c. of 10%  $\text{KH}_2\text{PO}_4$  solution. The total volume was kept at 90 c.c. The sol was dialysed for 3 days.

TABLE VI

Per litre.	Sol A.	Sol B.
Total iron	15.0768 g.	13.7866 g.
Combined phosphate ( $\text{PO}_4$ )	19.4000	15.2500
Combined iron	11.4000	8.9600
Free iron	3.6768	4.7760
Viscosity of sol (80°)	0.00872	0.00862
Bound water	0.4953	0.3207
Empirical formula	$\text{Fe}_2\text{O}_3 \cdot 6\text{FePO}_4 \cdot \text{H}_2\text{O}$	$5\text{Fe}_2\text{O}_3 \cdot 19\text{FePO}_4 \cdot 2\text{H}_2\text{O}$
Cl <sup>-</sup> ions per litre	1.8000 g.	3.3090 g.

## DISCUSSION

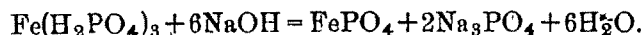
Usually when a dipotassium phosphate solution is added to an excess of ferric chloride, the substance precipitated is monohydrogen phosphate according to the following equation :



When the precipitation is carried out with potassium dihydrogen phosphate, the precipitate obtained is very likely ferric dihydrogen phosphate :



This is the expected composition of the positively charged ferric phosphate sol, obtained by peptising the ferric hydrogen phosphate with ferric chloride. But in the case of the negatively charged sols, which are prepared in presence of excess of alkali, the constitution probably corresponds to ferric *orthophosphate*,  $\text{FePO}_4^-$  :



In the course of dialysis most of the sodium phosphate, thus formed, is eliminated but the sol still contains a considerable amount of ferric phosphate. A portion of ferric phosphate is also hydrolysed during the course of peptisation or dialysis and the following equilibria are ultimately maintained :





The compositions of the negatively and the positively charged sols are given below. For comparison, positively charged sols have also been expressed in terms of  $\text{FePO}_4$ .

Negatively charged.

$8\text{Fe}_3\text{O}_8 \cdot 2\text{FePO}_4 \cdot 3\text{H}_2\text{O}$  (glucose peptised)

$5\text{Fe}_3\text{O}_8 \cdot 2\text{FePO}_4 \cdot 11\text{H}_2\text{O}$  (glycerine peptised)

Positively charged.

$\text{Fe}_2\text{O}_3 \cdot 6\text{FePO}_4 \cdot \text{H}_2\text{O}$

$5\text{Fe}_2\text{O}_3 \cdot 19\text{FePO}_4 \cdot 2\text{H}_2\text{O}$

From these compositions it is clear that the positively charged ferric phosphate sols contain a larger content of phosphate combined with iron than the negatively charged sols.

The temperature coefficients of the negatively charged ferric phosphate sols are of interest. The temperature coefficients are given below along with the conductivities at  $35^\circ$ .

	Conductivity at $35^\circ$ .	Tem. coeff. per $1^\circ$ .
Glucose sol (A)	$3.84 \times 10^{-4}$ mhos	0.066
Glycerine sol (B)	2.80	0.060

The temperature coefficient of sol A is thus 1.72% of the conductance at  $35^\circ$ , and that of sol B is 1.78% of the conductance at  $35^\circ$  i.e., the temperature coefficients per  $1^\circ$  of the sols are always less than 2% of the conductances at  $35^\circ$ .

In this paper the various characteristics of the negatively charged ferric phosphate sols have been reported. From the results recorded in the foregoing tables, the following observations may be summarised:

1. The electrical conductivities of the sols are proportional to the dilutions.

2. The electrical conductivities of the sols are linear functions of temperatures. The temperatures of zero conductance range between  $-22.0^\circ$  and  $-20.5^\circ$ .

3. The temperature coefficients of conductivity per  $1^\circ$  of the sols are always less than 2% of the conductances at  $35^\circ$ .

4. The ageing effect, as studied by the conductivity values, is equally prominent in both the sols. The conductivities increase when the sols age.

5. The extinction coefficients are proportional to the dilutions. The sols obey Beer's law.

6. The  $p_{\text{H}}$  values of the dispersion medium lie between 7.03 and 7.20 showing that the sols are slightly basic to the stabilising hydroxide ions.

7. The sols obey the Schulze-Hardy rule for the coagulation with electrolytes. They show the normal behaviour with dilution.

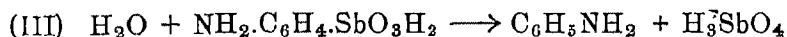
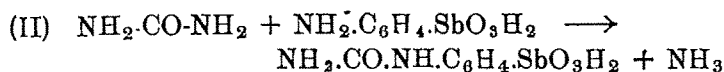
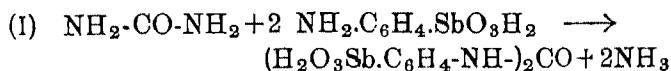
The author's grateful thanks are due to Dr. Satya Prakash for his kind interest in this investigation.

## ON THE COMPOSITION OF UREA STIBAMINE

BY S. DATTA AND T. N. GHOSH

The organo-antimonial constituents of urea stibamine, have been found, to be urea, *p*-acetamidophenylstibinic acid, *s*-diphenylcarbamido-4 : 4'-distibinic acid, and another organo-antimonial constituent, the constitution of which could not be ascertained.

Urea stibamine, introduced in India by Brahmachari (*Indian J. Med. Res.*, 1922, 10, 508 ; 1925, 13, 111) as a specific drug for the treatment of kala-azar, is formed by the interaction of urea with *p*-aminophenylstibinic acid (stibanilic acid). Regarded at first as a simple urea salt, it was later thought to be ammonium salt of 4-carbamidophenylstibinic acid,  $\text{NH}_2\cdot\text{CO}\cdot\text{NH}\cdot\text{C}_6\text{H}_4\cdot\text{SbO}_3\text{H}(\text{NH}_4)$ , a substance which has been synthesised by Niyogi (*J. Indian Chem. Soc.*, 1928, 5, 753). Subsequently, the detailed researches of Gray, Trevan, Bainbridge and Atwood (*Proc. Roy. Soc.*, 1931, 108, B, 54) have indicated that urea stibamine is probably a complex mixture containing not only the monocarbamide but also *s*-diphenylcarbamido-4 : 4'-distibinic acid,  $(\text{H}_2\text{O}_3\text{Sb}\cdot\text{C}_6\text{H}_4\cdot\text{NH})_2\text{CO}$ , which they have synthesised by the phosgenation of *p*-aminophenylstibinic acid. They consider that *p*-aminophenylstibinic acid, normally employed in the preparation of urea stibamine, apparently contains varying quantities of its acetyl derivative. When heated with urea, such impure specimens of stibanilic acid partly react with the urea forming the above distibinic acid, and partly undergo hydrolytic fission with the production of antimonious acid. In the pure state the above distibinic acid does not form salts with any appreciable solubility in water. When antimonious and *p*-acetamidophenylstibinic acid, however, are present, as in urea stibamine, its solubility is increased owing to the action of these substances as protective colloids. According to Gray *et al.*, the reaction between urea and *p*-aminophenylstibinic acid proceeds according to the following course :

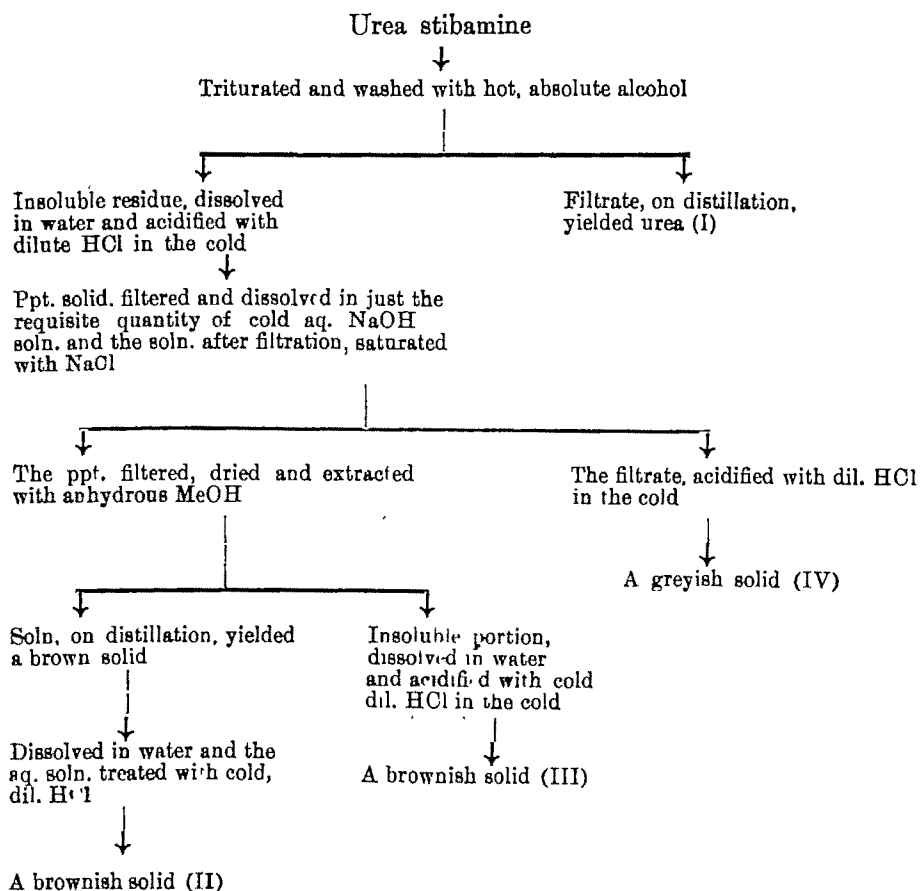


According to Gray *et al.*, the therapeutic activity of urea stibamine is largely due to *s*-diphenylcarbamido-4 : 4'-distibinic acid. In this connection it may be remarked that these authors have not tried to separate the different chemical constituents present in this drug, but have indicated the above course of reaction between urea and *p*-aminophenylstibinic acid on the basis of analyses of some samples of urea stibamine, prepared under different experimental conditions. It

has been therefore considered worthwhile at this stage to make attempts towards separation and characterisation of the different chemical constituents as present in this important drug.

The presence of free, uncombined urea in the urea stibamine and its influence on the toxicity of the drug have already been pointed out (Datta, Ghosh and Bose, *Science & Culture*, 1945, 11, 143). The percentage of free, uncombined urea varies, however, with different samples of the drug. It has also been shown that the drug contains some ammonium salt and that the replacement of the ammonium radical by hydrogen renders the compound insoluble in water. It has also been found that, besides some organo-antimonial constituents, urea stibamine contains varying quantities (though, very small) of antimonious and antimonous acids, the presence of which exerts a pronounced influence on the toxicity of the drug (Datta, *et al*, *loc. cit.* Bose, Ghosh, Mitra and Datta, *Indian Med. Gaz.*, 1946, 81, 13).

The following scheme, based on a study of the properties of the various constituents of the drug, as envisaged by Gray *et al.*, has now been adopted for the separation and characterisation of the various organo-antimonial constituents.



Following the above scheme, the organo-antimonial constituents of urea stibamine have been found to be (*vide* Experimental) (I) free, uncombined urea, (II) *p*-acetamidophenylstibinic acid, and (III) *s*-diphenylcarbamido-4 : 4'-distibinic acid. The fourth constituent (compound IV), as analysed, does not, however, conform to the formula of 4-carbamidophenylstibinic acid. Its exact chemical nature, however, could not be ascertained. It is difficult to ascertain whether 4-carbamidophenylstibinic acid is absent or present in the particular sample of urea stibamine examined and has been decomposed during separation of the constituents. In this connection, it should be mentioned that according to Gray *et al.* (*loc. cit.*) the concentration of urea in the preparation of urea stibamine plays an important part in the chemical composition of urea stibamine. According to these authors, a low concentration favours the formation of *s*-diphenylcarbamido-4 : 4'-distibinic acid, whereas, a high concentration of urea leads to the formation of 4-carbamidophenylstibinic acid. The resulting product (Urea Stibamine) in the former case has been found to possess pronounced trypanocidal action, whereas in the latter case, the product has been found to be comparatively inactive.

The percentage of the constituents mentioned above differs, however, with different samples and is dependent on the experimental conditions employed for the preparation of this drug. With regard to the constituent (II), it has been shown by Gray *et al.* (*loc. cit.*) that *p*-aminophenylstibinic acid, prepared according to published directions, invariably contains varying amounts of *p*-acetamidophenylstibinic acid. It has been subsequently shown by Datta, Ghosh and Bose (*Science & Culture*, 1945-46, 11, 385) that the ease with which commercial *p*-aminophenylstibinic acid reacts with urea is attributed to the presence of traces of the acetyl compound.

## EXPERIMENTAL

*Separation of the Organo-antimonial Constituents of Urea Stibamine : Isolation of Urea (I), p-Acetamidophenylstibinic acid (II) and s-Diphenylcarbamido-4 : 4'-distibinic acid (III).*—A sample of well powdered urea stibamine (10 g.) was triturated and washed 2 to 3 times with hot absolute alcohol (total 100 c. c.). The alcoholic filtrate, on distillation under reduced pressure, yielded a solid which on crystallisation was proved to be urea (yield 0.3 g.).

The residue, left after treatment with alcohol, was dissolved in cold water and treated with well cooled hydrochloric acid (1%) till distinctly acidic to litmus, when a heavy precipitate was obtained. The precipitate was filtered and washed with cold water till free from hydrochloric acid. The solid was next treated with 20% caustic soda solution (ice-cooled) till just alkaline to litmus and the solution, after filtration to remove minute quantity of insoluble matter, was gradually saturated with chemically pure sodium chloride, when a heavy precipitate (P) was obtained, which was allowed to stand for some time and then filtered, and the filtrate (F) preserved for subsequent treatment,

The precipitate (P) was dried in a partially exhausted desiccator and then thoroughly triturated and washed 2 to 3 times with hot, anhydrous methyl alcohol (total 125 c. c.). The insoluble residue (R) was preserved for subsequent treatment. The methyl alcohol filtrate, on distillation under reduced pressure, left a brown solid which was next dissolved in water. The aqueous solution, when treated with cold hydrochloric acid (1%), yielded a brownish solid (II, 0.7 g.) which was thoroughly washed with cold water and dried in a partially exhausted desiccator. (Found : N, 3.99 ; Sb, 40.53.  $C_8H_{10}O_4NSb$  requires N, 4.57 ; Sb, 39.82 per cent).

The residue (R) was dissolved in cold water and the solution, when treated with cold hydrochloric acid (1%), gave a precipitate which was thoroughly washed with water and dried, yield 4.8 g. It was purified by solution in cold alkali and precipitation by cold, dilute hydrochloric acid, when a brownish solid (compound III) was obtained which was dried in a partially exhausted desiccator. (Found : N, 4.26 ; Sb, 43.4.  $C_{13}H_{14}O_7N_2Sb_2$  requires N, 5.05 ; Sb, 43.99 per cent).

The filtrate (F) was cooled in ice and then slowly acidified with cold dilute hydrochloric acid (1%), when a precipitate was obtained, which was thoroughly washed with cold water and dried in a partially exhausted desiccator, when a greyish solid (compound IV ; 2.4 g.) was obtained. (Found : N, 3.0 ; Sb, 40.6 per cent). The analytical figures of this compound (IV) do not conform to the formula of 4-carbamidophenylstibinic acid and its exact chemical nature could not be ascertained.

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*Received April 9, 1947.*

## THERMAL DECOMPOSITION OF IRON PYRITES

BY MUKARRAM H KHUNDKAR

Thermal decomposition of iron pyrites (500°-800°) shows that by application of heat alone only half of the sulphur content of the ore is liberated.

That iron pyrites, when heated in absence of air, liberates sulphur, was known for a long time. Marchal (*Bull. soc. chim.*, 1924, *iv*, 35, 43) observed that the dissociation of iron pyrites (into ferrous sulphide and sulphur) in vacuum began at 500° and was complete in 2 hours at 850°. At higher temperatures (1200°) she detected the presence of a small amount of iron. X-ray investigations by de Jong and Willems (*Z. anorg. Chem.*, 1927, **161**, 311) showed that the reaction took place according as  $2\text{FeS}_2 \rightarrow 2\text{FeS} + \text{S}_2$ . D'Or (*Compt. rend.*, 1930, **190**, 1296; *J. chim. phys.*, 1930, **27**, 239; 1931, **28**, 377) supported Jong and Willems' views on the mechanism of dissociation by means of spectroscopic analyses. Udintzeva and Tschufarov (*J. Appl. Chem. Russia*, 1941, **14**, 3) has pointed out that the velocity of the reaction  $\text{FeS}_2 \rightarrow \text{FeS} + \text{S}$  is, within certain limits, proportional to the temperature and inversely proportional to the diameter of the particles and the pressure. In a previous communication, Chowdhury and Hussain (*J. Indian Chem. Soc. Ind. & News Ed.*, 1945, **8**, 81) discussed the results of dry chlorination of iron pyrites between 500° and 800°. The purpose of the present investigation was to ascertain the rôle played by chlorine and the dissociation of the pyrites within the range of the experiment. The dissociation reaction was carried out under conditions exactly the same as that of chlorination.

### EXPERIMENTAL

The tube containing the ore (10 g.) being kept in position as usual, the air inside the tube was completely displaced by carbon dioxide. This being ensured, the carbon dioxide supply was cut off and the temperature of the furnace was raised to the desired degree, and kept constant for 6 hours. The elementary sulphur, set free, collected in the cooler parts of the tube. After the reaction, the elementary sulphur was dissolved out with carbon disulphide and estimated. The residual ore was digested and the total sulphur in it estimated. The total of the elementary sulphur liberated and the residual sulphur in the ore were always found short of the total sulphur input by 3 to 4%. This was supposed mainly due to the loss incurred in collecting the sulphur from the tube. Taking the dissociation process as represented by the equation  $\text{FeS}_2 \rightarrow \text{FeS} + \text{S}$ , it is easy to see that half the amount of total sulphur, initially contained in the portion of the ore undergoing dissociation, comes out as elementary sulphur. So the extent of the dissociation is given by doubling the percentage of the elementary sulphur formed. The results obtained are tabulated below.

TABLE I

*Dissociation under normal atmospheric pressure.*

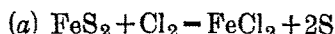
Ore taken = 10 g. (40 - 60 mesh).

Temp.	Yield of elem. S	Unreacted S	Total S accounted for.	% Dissociation.
500°	2.21%	96.00%	98.21%	4.42
550°	6.01	90.58	96.59	12.02
600°	34.12	62.80	96.92	68.24
700°	39.57	56.82	96.39	79.14
800°	42.97	52.92	95.89	85.94

The percentage dissociation when plotted against temperature (fig. not shown) shows that the extent of dissociation sharply changes between 550° and 600°. Below 550°, the dissociation is practically nil. at 600° the percentage is considerably high. This again increases with temperature.

From the results it appears that with the application of heat alone, nearly half the total sulphur contained in the ore can be extracted by working at a temperature slightly higher than 800°. On a superficial view this may appear to be a very prospective way of extracting sulphur from pyrites. But a careful consideration shows that the observation is of little importance from an economic point of view. The residue of dissociation still contains half of the sulphur content of the ore, and the extraction of only half (simultaneously wasting the other half) cannot be expected to be economic.

And if the residue be later subjected to the action of chlorine to extract all the total sulphur content of the residue, the amount of chlorine necessary should be exactly the same as that required for chlorinating pyrites directly. This becomes evident from the following equations :



This inference from the stoichiometric relationship has also been confirmed by carrying out a few experiments in two steps.

It is interesting to note that the temperature (600°) at which the percentage dissociation suddenly becomes very high is also the temperature which is optimum for the chlorination of the ore for obtaining sulphur. The reasons for this coincidence are still obscure.

The author's thanks are due to Prof J. K. Chowdhury for his valuable suggestions.

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THE STRUCTURE OF MOLECULAR COMPOUNDS. PART II.  
THE MAGNETIC SUSCEPTIBILITIES OF THE MOLECULAR  
COMPOUNDS OF 2 : 4-DINITROPHENOL AND  
2 : 4-DINITROCHLOROBENZENE WITH  
HYDROCARBONS, PHENOLS  
AND AMINES

BY (Miss) BIMALA PURI, ROOP CHAND SAHNEY, MAHAN SINGH  
AND SURJIT SINGH

Magnetic susceptibilities of the molecular compounds 2 : 4-dinitrophenol and 2 : 4-dinitrochlorobenzene with hydrocarbons phenols and amines have been measured and the results have been explained by taking into account the various resonance forms of the components in relation to the structure of molecular compounds.

In Part I (Shaney and Singh, *J. Indian Chem. Soc.*, 1946, 23, 335) we reported the magnetic susceptibilities of the molecular compounds of trinitrobenzene with hydrocarbons and phenols. Powell *et al.* (*J. Chem. Soc.*, 1943, 153, 435) have shown that molecular compound formation between trinitrobenzene and *p*-iodoaniline is not due to the formation of any co-valent bond between the molecules. The view that the properties of these molecular compounds may be explained by assuming the formation of these through transfer of an electron from a hydrocarbon to the polynitro compound (Weiss, *J. Chem. Soc.*, 1942, 245) has not been supported by the study of their melting points and the intensities of X-ray including diffuse spectra (Powell, *ibid.*, 1943, 435).

We have expressed the view (Singh, *et al.*, *loc. cit.*) that the various resonance forms of the components play an important part in the formation of these complexes. We have extended this work to the molecular compounds of 2 : 4-dinitrophenol and 2 : 4-dinitrochlorobenzene with hydrocarbons, phenols and amines.

### E X P E R I M E N T A L

The molecular compounds were obtained by boiling alcoholic solutions of the components in molecular proportions. The compounds were repeatedly crystallised till their melting points agreed with those given in the literature.

#### *Magnetic Susceptibility Determination*

The magnetic susceptibility determinations of the substances were carried out on the modified form of Guoy's balance (Shaney and Singh, *loc. cit.*). Conductivity water with  $\chi_M 0.72 \times 10^{-6}$  was taken as the reference substance. The apparatus was standardised by taking a number of observations on substances with known magnetic susceptibility values. The susceptibilities of the known substances with %error are given in Table I, those of the components and compounds in Table II, and the comparison of the magnetic susceptibilities of the molecular compounds with the additive sum of the  $\chi_M$  of components, in Table III.

TABLE I

No.	Substance.	$\chi_M \times 10^{-6}$		
		Exp.	Reported.	% Deviation.
1.	Potassium chloride	0.515	0.510	0.2
2.	Naphthalene	0.718	0.717	0.15
3.	Benzene	0.710	0.712	0.15
4.	2 : 4-Dinitrophenol	0.895	0.897	0.30
5.	Ethyl alcohol	0.746	0.744	0.20



TABLE II

No.	Substance.	Mol. weight,	Expt. mean of 3 readings.	
			$\chi \times 10^6$	$\chi_M \times 10^{-6}$ per g. mol.
1.	Naphthalene	128	0.708	91.9
2.	$\alpha$ -Naphthylamine	143	.690	86.67
3.	Benzidine	184	.626	115.18
4.	Aniline	93	.691	84.26
5.	$\alpha$ -Naphthol	144	.672	96.77
6.	$\beta$ -Naphthol	144	.672	96.77
7.	2 : 4-Dinitrophenol	184	.3935	72.31
8.	2 : 4-Dinitro-1-chlorobenzene	202	.418	84.44
9.	2 : 4-Dinitrophenol-naphthalene	312	.5455	170.35
10.	2 : 4-Dinitrophenol- $\alpha$ -naphthyl-amine	327	.5823	173.96
11.	2 : 4-Dinitrophenol-benzidine.	368	.52855	194.67
12.	2 : 4-Dinitrophenol-aniline	277	.4832	133.79
13.	2 : 4-Dinitro-1-chlorobenzene-naphthalene	330	.5495	181.335
14.	2 : 4-Dinitro-1-chlorobenzene- $\alpha$ -naphthol	346	.48104	166.426
15.	2 : 4-Dinitro-1-chlorobenzene- $\beta$ -naphthol	346	.55309	153.278
16.	2 : 4-Dinitro-1-chlorobenzene-aniline	295	.4804	141.6
17.	2 : 4-Dinitro-1-chlorobenzene- $\alpha$ -naphthylamine.	345	.5501	193.20

TABLE III

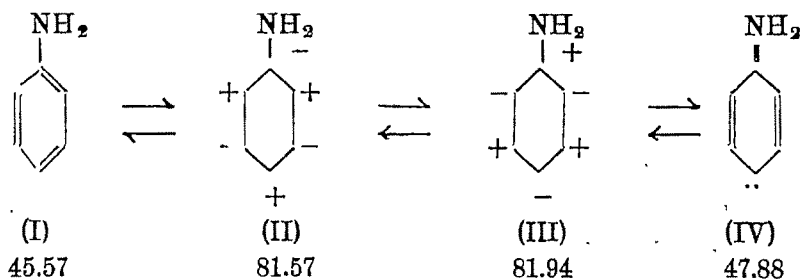
No.	Compounds.	$\chi_M \times 10^{-6}$ per g. mol.		Diff. between (1) and (2).
		Expt. (1)	Additive sum of components. (2)	
1.	2 : 4-Dinitrophenol-naphthalene	170.35	164.216	-6.136
2.	2 : 4-Dinitrophenol- $\alpha$ -naphthylamine	173.964	170.982	-2.982
3.	2 : 4-Dinitrophenol-benzidine	194.672	187.496	-7.176
4.	2 : 4-Dinitrophenol-aniline	133.791	136.576	+2.784
5.	2 : 4-Dinitro-1-chlorobenzene-naphthalene	181.335	176.340	-4.996
6.	2 : 4-Dinitro-1-chlorobenzene- $\alpha$ -naphthol	183.20	188.106	+4.906
7.	2 : 4-Dinitro-1-chlorobenzene- $\beta$ -naphthol	166.426	181.204	+14.728
8.	2 : 4-Dinitro-1-chlorobenzene-aniline	153.278	181.204	+27.926
9.	2 : 4-Dinitro-1-chlorobenzene- $\alpha$ -naphthylamine	141.6	148.699	+7.097

## DISCUSSION

Column 5 of Table III shows that the differences between the values of  $\chi_{AB}$  and the sum of  $\chi_A$  and  $\chi_B$  vary within a wide range and do not follow any sequence; they cannot therefore be due to any chemical linkage. Further, the differences are too big to be due to simple physical forces, such as weak Van der Waal's forces or the packing of the molecules.

These results, as shown in Part I (*loc. cit.*), can be readily explained by taking into account the various resonance forms of the components.

Aniline can occur in the following resonance forms.

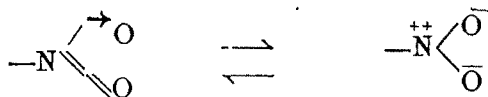


The mean of the above values is 64.25 which agrees closely with the experimental value of 64.35. The four resonance forms therefore contribute equally to the aniline molecule. The molecular compounds of aniline with 2:4-dinitrophenol and 2:4-dinitro-1-chlorobenzene are less diamagnetic than the sum of  $\chi$  of their components. It is probable that the molecular compound formation is due to the polarised forms of dinitro compounds with structures (I) and (IV) of aniline which would cause depression in the magnetic susceptibilities. The results of other compounds of 2:4-dinitrophenol and 2:4-dinitro-1-chlorobenzene with hydrocarbons and amines can be similarly explained.

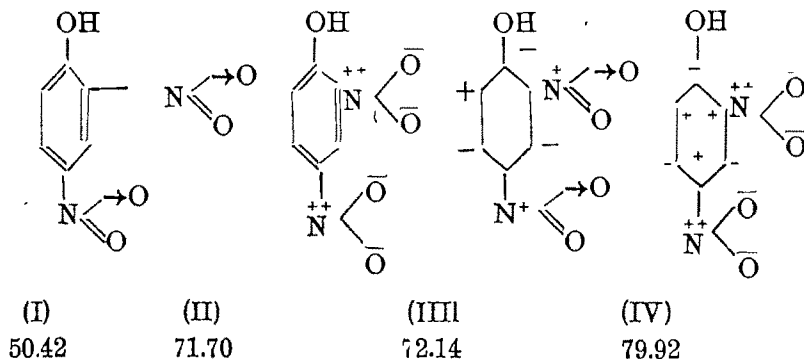
According to Briegleb (*Z. Physik*, 1932, 19, 255; 1934, 26, 63) the molecular complexes are the products of electrostatic interaction between the nitro group and the electric dipoles induced or already present in aromatic hydrocarbons and bases. The dipole aggregates can be set either side by side  $\leftrightarrow$  or end to end  $\leftrightarrow$ . The permanent dipoles of the nitro group might be expected to interact according to the first mode of representation. It has been also suggested that the colour producing interactions such as take place between trinitrobenzene and naphthalene are of the end to end type and they may be regarded as the incipient oxidation-reduction processes. Only small differences between the experimental values can be expected if the phenomenon of the above type takes place. But as mentioned above, in many cases, the differences are quite large.

These results, as shown in Part I, can be readily explained by taking into account the various resonance forms of the components.

2 : 4-Dinitrophenol has the following structures due to the corresponding resonance of the nitro group between



and the ring ionisation.



The theoretical calculations for the different resonating forms have been made by Gray and Cruickshank's method as described in Part I (*loc. cit.*). The experimental value of  $\chi_m$  72.31 shows that the structures (II) and (III) predominate. Under proper conditions of activation, which are provided by the presence of the second anisotropic and polarisable component, there is an adjustment in the relative contributions of the different forms.

Let us take the case of 2 : 4-dinitrophenol-naphthalene complex. Naphthalene can occur in a number of forms (*loc. cit.*). The experimental value of  $\chi_m$   $91.7 \times 10^{-6}$  for naphthalene corresponds to the structures in which one of the rings is double bonded and the other ionic. The magnetic susceptibility of the above complex is greater than the sum of the components (*vide* Table III). This increase is due to the greater contribution of the polarised form (IV) of 2 : 4-dinitrophenol.

Again, let us take the case of aniline which can occur in the resonance forms as cited above. The mean of the above values is 64.25 which agrees closely with the experimental value of 64.35. The four resonance forms therefore contribute equally to the aniline molecule. The molecular compounds of aniline with 2 : 4-dinitrophenol and 2 : 4-dinitro-1-chlorobenzene are less diamagnetic than the sum of  $\chi_m$  of their components. It is obvious that the molecular compound formation is due to the polarised forms of dinitro compounds with structures (I) and (IV) of aniline which would cause depression in the magnetic susceptibilities.

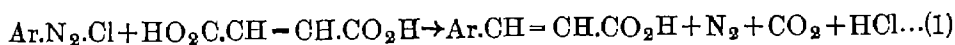
This work is being continued.

# CONDENSATIONS OF ARYL DIAZONIUM SALTS WITH REACTIVE UNSATURATED COMPOUNDS. PART III. ACTION OF ARYL DIAZONIUM CHLORIDES WITH ACRYLIC ACID

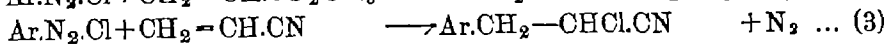
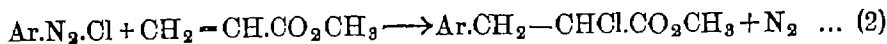
BY JASWANT RAI AND KUNJ BEHARI LAL MATHUR

The condensations afford a more practical way for the synthesis of cinnamic acids than the Koelsch's method.

In Part II of this paper (*this issue*, p.383), the condensations of aryl diazonium chlorides having a negative substituent were effected with maleic acid in the presence of copper chloride and sodium acetate, resulting in the formation of cinnamic acids, thus :



and contrary to expectation, the use of acetone was found unnecessary and harmful. The cinnamic acids could be easily obtained in a sufficient state of purity from the reaction mixture as to merit the reaction fit for preparatory purpose. Earlier, Koelsch (*J. Amer. Chem. Soc.*, 1943, 65, 57) had reacted four aryl diazonium chlorides with methyl acrylate and acrylonitrile and from the methyl  $\alpha$ -chlorohydrocinnamates and  $\alpha$ -chlorohydrocinnamitriles so formed :



obtained the cinnamic acids after their dehalogenation and hydrolysis. In the present investigation aryl diazonium chlorides have been condensed with acrylic acid to ascertain how far the reactions compare with Koelsch's method for obtaining cinnamic acids.

When the various aryl diazonium chlorides are reacted (vide experimental) with acrylic acid in the presence of copper chloride and sodium acetate, but in the absence of acetone, condensations occur to afford the cinnamic acids directly, thus



(I)

with only traces of the  $\alpha$ -halogenated hydrocinnamic acids which give (I) even during extraction of the reaction products with warm aqueous sodium bicarbonate. The condensations have been effected in larger dilution than those with maleic acids and the yields of cinnamic acids by the two methods compare admirably.

The yields of the cinnamic acids indicate that acrylic acid can adequately replace the use of its methyl ester or the nitrile. The preparation of *p*-nitrocinnamic acid by the present method is definitely superior to that of the Koelsch's procedure. The acid is obtained in larger yield than the nitrile in the latter method and the task of handling a black tarry reaction product

is obviated. In other cases, although Koelsch's method gives relatively a large yield of the condensation products, the loss sustained in obtaining the free cinnamic acids after their hydrolysis would counterbalance this advantage. Moreover, the omission of acetone as solvent, and the direct use of only aqueous acrylic acid are the added advantages.

It may be recalled that when of *p*-nitrobenzene diazonium chloride is reacted with crotonic acid (Koelsch and Boekelheide, *J. Amer. Chem. Soc.*, 1944, **66**, 414), the reaction mixture yields only a tarry mass from which the acid of m.p. 167-68° (cf. also Meerwein *et al.*, *J. prakt. Chem.*, 1939, *ii*, 152, 261) could be obtained after esterification of the tarry mass and its subsequent hydrolysis. It is now found that even when the use of acetone is omitted in this reaction, aqueous sodium bicarbonate, as is done in experiments with acrylic acid, is able to extract out only a tarry acid from the reaction product.

#### EXPERIMENTAL

The amines were of the quality mentioned in a previous investigation (*loc. cit.*).

The acrylic acid was obtained in a batch preparation by boiling for 2 to 3 hours  $\beta$ -chloropropionic acid (25 g.) with 2*N* aqueous sodium hydroxide (500 c.c.). The alkaline liquor was acidified with dilute sulphuric acid (1 : 5, 125 c.c.) and then distilled till about 400 c.c. were collected as the distillate. An aliquot of 80 c.c. of the distillate contained 1.8 g. of acrylic acid (*M*/40) as determined alkalimetrically, and this much solution was used in each experiment with acrylic acid.

#### *Condensations of various Aryl Diazonium Chlorides with Acrylic Acid in the presence of Sodium Acetate and Copper Chloride*

The amines (0.025 *M*) in hydrochloric acid (conc., 6 c.c.) and water (9-12 c.c.) were diazotised with sodium nitrite (2.5 g., 68% pure) in water (7 c.c.) as in the previous investigation. In a separate beaker were taken aqueous solution of acrylic acid (80 c.c., *vide supra*), sodium acetate (5.75 g.) and copper chloride (1 g.). Each diazotised amine was condensed with such a mixture. The total bulk of the solution was about 100 c.c. Reactions were vigorous with the nitro- and halogen-substituted diazonium chlorides. Reaction mixtures with the *o*-nitro-, and the 2 : 6-dichlorobenzene diazonium chlorides (*vide infra*) contained more tarry matter. In every case the insoluble residue was filtered off from the reaction mixture and extracted with 5% aqueous sodium bicarbonate. This treatment also eliminated whatever little halogen acid was there in the crude product. The acids, obtained on acidification with dilute sulphuric acid, were found to be unsaturated, and after purification were found to possess melting points which were not depressed when they were mixed with a corresponding aryl acrylic acid, prepared by the maleic acid method. The results are recorded in the following table.

No acid could be obtained from diazotised aniline, *o*-xylydine, *o*- and *p*-anisidines and *p*-aminoacetanilide.

TABLE I  
 $\beta$  Aryl acrylic acid

Amine (diazotised).	Wt.	Amount.	Yield.	M.p. & mixed m.p.	Equivalent		*Yield of the pure nitrile.
					Found.	Calc.	
<i>p</i> -Nitroaniline	(3.45 g.)	2.9 g.	60.1%	285-86°	194	193	48%
<i>p</i> -Chloroaniline	(3.20 g.)	1.3	28.5	239-40°	186	182.5	—
<i>p</i> -Bromoaniline	(4.30g.)	1.5	26.5	249-51°	232	227	—
<i>m</i> -Nitroaniline	(3.45g.)	1.4	29.0	195-96°	195	193	38%
<i>m</i> -Chloroaniline	(3.20g.)	1.3	28.0	174-75°	186	182.5	—
<i>m</i> -Bromoaniline	(4.30g.)	1.5	26.5	175-77°	234	227	—
<i>o</i> -Nitroaniline	(3.45g.)	0.3	7.3	238-39°	197	193	—
<i>o</i> -Chloroaniline	(3.20g.)	1.2	26.0	198-99°	188	182.5	—
<i>o</i> -Bromoaniline	(4.30g.)	1.4	25.2	210-12°	230	227	—
<i>o</i> -Iodoaniline	(2.70g., <i>M</i> /80)	0.9	25.6	212-14°	—	—	—
4-Methyl-3- nitroaniline	(3.80g.)	0.8	15.4	170-72°	212	207	—
2:6-Dichloro- aniline	(3.60g.)	1.1	19.8	181-88°	220	217	—
$\alpha$ -Naphthylamine	(3.60g.)	0.3	7.0	205-08°	—	—	—
$\beta$ -Naphthylamine	(3.60g.)	0.5	10.0	193-95°	201	198	—

\*Koelsch's method.

The experiment of the reaction of *p*-nitrobenzene diazonium chloride with crotonic acid (prepared from paraldehyde, malonic acid and glacial acetic acid) was also repeated. The reaction product on extraction with sodium bicarbonate yielded only a tarry mass. The latter was obtained more in amount in the absence of acetone than in its presence. The tarry acid mass polymerised to an amorphous solid on keeping.

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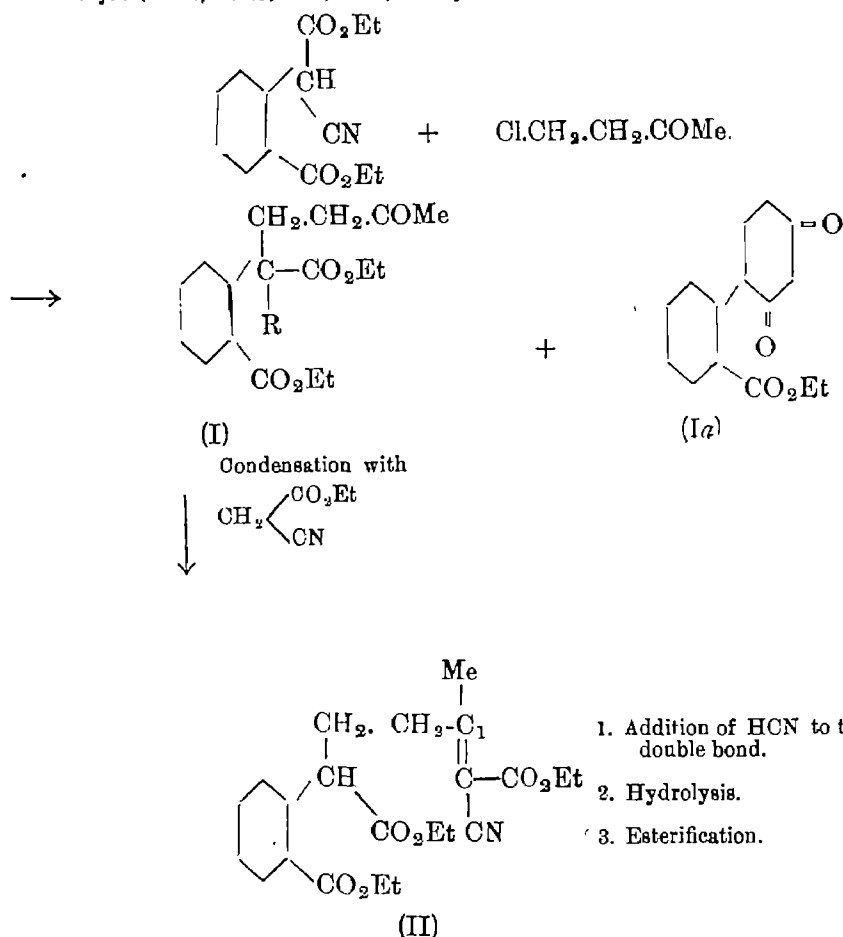
# SYNTHETIC INVESTIGATIONS IN DICYCLOHEXANE DERIVATIVES. PART I.

BY BIDYUT KAMAL BHATTACHARYYA

Ethyl 2-cyano-2-(2'-carbethoxycyclohexyl)-4-acetyl-butyrates, obtained from ethyl 2-carb-ethoxycyclohexylcyanoacetate, on condensation with ethyl cyanoacetate, followed by addition of hydrocyanic acid, hydrolysis and esterification, furnishes (III,  $R_1=CO_2Et$ ;  $R_2=H$ ) which on cyclisation, methylation, hydrolysis and esterification yields (IV;  $R=H$ ). The keto-ester on Reformatsky's reaction, followed by dehydration and hydrogenation yields (V).

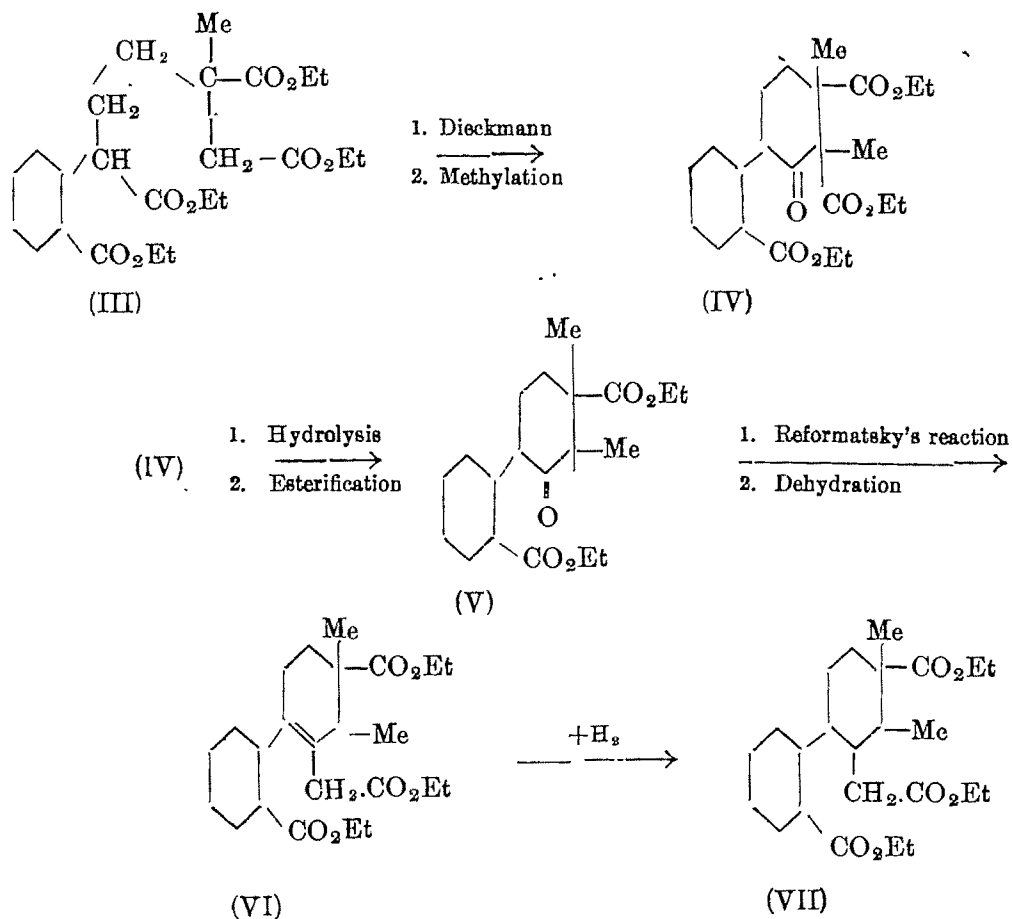
In order to investigate the possibility of extending the method of synthesis of *trans-anti-trans*-perhydrophenanthrene (Bhattacharyya, *J. Indian Chem. Soc.*, 1945, 22, 85) for the preparation of *cyclopentanoperhydrophenanthrene*, the following pilot experiments have been performed.

The sodio derivative of ethyl 2-carbethoxycyclohexyl-1 cyanoacetate has been condensed with 4-chlorobutan-2-one in benzene solution according to the method of Banerjee (*ibid.*, 1940, 17, 453) to yield (I;  $R=CN$ ). The substituted



4-acetyl butyrate is best hydrolysed with an excess of concentrated hydrochloric acid to the dibasic acid, which is esterified. The resulting keto-ester (I;  $R=H$ )

condenses with ethyl cyanoacetate according to the modified method of Cope *et al.* (*J. Amer. Chem. Soc.*, 1941, 63, 3452) to give diethyl 1-(2'-carbethoxycyclohexyl)-4-methyl-5-cyanopent-4-ene-1:5-dicarboxylate (II), which smoothly adds a molecule of hydrocyanic acid. The above succinic acid system on hydrolysis, followed by esterification, yields (III). The tetracarboxylic ester has been cyclised and methylated *in situ* to yield (IV), which can be distilled with slight decomposition. The above compound has been hydrolysed and esterified when (V) is obtained. The Reformatsky's reaction on the above keto-ester, followed by dehydration and hydrogenation, yields ethyl 2'-carbethoxy-3:4-dimethyl-4-carbethoxy-dicyclohexyl-2-acetate (VII).



#### EXPERIMENTAL

*Ethyl 2-Cyano-2-(2'-carbethoxycyclohexyl)-4-acetyl-butyrat* (I ; R = CN).—Ethyl 2-carbethoxycyclohexylcyanoacetate (40 g.) was added to sodium dust (3.54 g.) covered with benzene (87 c.c.). After sometime sodium metal went into solution with the development of a red colour. The clear solution was cooled



in ice and then a solution of 4-chlorobutan-2-one (16 g.) in benzene (30 c.c.) was added when, however, heat was generated and the colour of the solution became light yellow. On standing for a few minutes a gelatinous mass was formed throughout the whole of the solution. The flask was allowed to stand overnight and then refluxed for 30 hours. The reaction mixture was diluted with water and the resulting benzene layer was washed thrice with water, dried and distilled, b.p.  $215^{\circ}/5$  mm., yield 20 g. (Found: C, 63.98; H, 8.12.  $C_{18}H_{27}O_5N$  requires C, 64.09; H, 8.01 per cent).

The *semicarbazone* was first obtained as a liquid, but solidified after a few months. On crystallisation from alcohol it melted at  $115^{\circ}$ . (Found: N, 14.51.  $C_{19}H_{30}O_5N_4$  requires N, 14.21 per cent).

During the distillation decomposition set in, hence rapid distillation was essential. The condensation of the cyano-ester with methiodide of 4-diethylaminobutan-2-one, according to the method of Du Feu, McQuillin and Robinson (*J. Chem. Soc.*, 1937, 53) and Wilds and Shunk (*J. Amer. Chem. Soc.*, 1943, 65, 471), gave a very poor yield of the condensation product.

6-(2'-*Carbethoxycyclohexyl*)-cyclohexane-1 : 3-dione (Ia).—The above substituted cyano-ester was refluxed with a mixture of sulphuric and acetic acids and water (5 : 7 : 7) for 35 hours. The crude acid fraction thus obtained was esterified and distilled. The boiling point was not constant, but the fraction boiling at  $140-50^{\circ}/5$  mm. was the expected dione (II). (Found: C, 67.4; H, 8.3.  $C_{15}H_{22}O_4$  requires C, 67.7; H, 8.3 per cent).

*Ethyl* 2-(2'-*Carbethoxycyclohexyl*)-4-*acetyl-butyrates* (I; R=H).—The above substituted cyano-ester (I, 20 g.) was refluxed with hydrochloric acid (conc., 200 c.c.) for 36 hours. The precipitated oil was extracted thoroughly with ether which was dried over anhydrous sodium sulphate. On evaporation of the ether the residue was dried in a pump and esterified with alcohol (60 c.c.) and sulphuric acid ( $d$  1.84, 6 c.c.). The reaction mixture was diluted with ice-water and the precipitated oil was extracted with ether. The ethereal layer was washed with sodium bicarbonate solution, water and dried over anhydrous sodium sulphate. The ether was evaporated and the residue distilled, b.p.  $148-55^{\circ}/2$  mm. (Found: C, 65.13; H, 8.88.  $C_{17}H_{28}O_6$  requires C, 65.38; H, 8.97 per cent). The *semicarbazone* as well as the oximes of this keto-ester are liquids.

*Diethyl* 1-(2'-*Carbethoxycyclohexyl*)-4-*methyl-5-cyano-pent-4-ene*-1 : 5-*dicarboxylate* (II).—The above keto-ester (50 g.) together with ethyl cyanoacetate (19 c.c.), acetic acid (4 c.c.), ammonium acetate (4g.) and benzene (50 c.c.) was taken in a flask fitted with the apparatus recommended by Cope *et al.* (*loc. cit.*) and refluxed for 12 hours. Afterwards another lot of ammonium acetate (3 g.) and acetic acid (3 c.c.) was added and the refluxing was continued for another 6 hours. The reaction mixture was taken in benzene and washed several times with water. The benzene solution was dried and distilled, b.p.  $201-5^{\circ}/1.5$  mm.; yield 34 g. (Found: C, 64.80; H, 8.0.  $C_{22}H_{33}O_6N$  requires C, 64.86; H, 8.1 per cent).

*Diethyl 1-(2'-Carbethoxycyclohexyl)-4-methyl-4-carbethoxy-pentane-1:5-dicarboxylate* (II).—To the solution of the above unsaturated ester (34 g.) in alcohol (94.6 c.c.) and water (4.9 c.c.) was added slowly a solution of potassium cyanide (10.89 g.) in water (59.1 c.c.) when some heat was developed. This mixture of the reaction product and the reactants were cooled in ice-water for half an hour and then very slowly was added to it hydrochloric acid (conc., 14 c.c. and 93 c.c. of water) which was previously cooled for half an hour. After the addition of the acid, the mixture was cooled for further 20 minutes. Next it was poured into ice-cold dilute hydrochloric acid and the precipitated oil was extracted with ether. The ether was driven off and the residue was hydrolysed by refluxing it with concentrated hydrochloric acid (500 c.c.) for 48 hours. The clear solution was extracted twice with ether and then the mother-liquor was saturated with ammonium sulphate. The saturated solution was extracted seven times with ether. Both the ethereal solutions were dried over anhydrous sodium sulphate. The ether was driven off and the residue was esterified with alcohol (200 c.c.) and sulphuric acid (36 c.c.) by refluxing the mixture for one week. The ester was worked up in the above way and distilled, b.p. 205-10°/3 mm., yield 33 g. (Found : C, 63.23 ; H, 8.68.  $C_{24}H_{40}O_8$  requires C, 63.16 ; H, 8.77 per cent).

*2-(2'-Carbethoxycyclohexyl)-5 : 6-dimethyl-5-carbethoxycyclohexanone* (V).—The tetra-ester (20 g.) was refluxed with sodium dust (2 g.), benzene (50 c.c.) and alcohol (1 c.c.) on the water-bath for 3½ hours, when all the sodium metal reacted. The reaction mixture was decomposed with iced dilute sulphuric acid. The benzene layer was washed with dilute sodium bicarbonate solution and water and then dried over calcium chloride. The benzene layer was driven off; the residual  $\beta$ -keto-ester, which furnished a positive ferric reaction, could not be distilled. The  $\beta$ -ketonic ester was dried under vacuum at 100° and treated with sodium dust (0.8 g.) and benzene (45 c.c.). The resulting sodio derivative was reacted with methyl iodide (2 moles) and refluxed for 7 hours. The methylated product in benzene was washed with water, dried and distilled with slight decomposition, b.p. 200-210°/4.5 mm., yield 10 g. It did not respond to ferric reaction. (Found : C, 66.1 ; H, 8.00.  $C_{23}H_{36}O_7$  requires C, 65.09 ; H, 8.5 per cent). The high result of the analysis is due to a slight decomposition.

The above substituted  $\beta$ -keto ester (10 g.) was refluxed with hydrochloric acid ( $d$  1.19, 100 c.c.) for 40 hours. It was extracted with ether and esterified with alcohol (100 c.c.) and sulphuric acid (10 c.c.), b.p. 185°/3.5 mm., yield 5.5 g. (Found : C, 68.46 ; H, 8.91.  $C_{20}H_{32}O_5$  requires C, 68.18 ; H, 9.09 per cent).

*Ethyl 2'-Carbethoxy-3 : 4-dimethyl-4-carbethoxy-dicyclohexyl-2-acetate* (VII).—A solution of the above keto-ester (5.5 g.) in thiophen-free benzene (40 c.c.) was heated with activated zinc (8 g.), a crystal of iodine and ethyl bromoacetate (4 c.c.) on the water-bath to drive away some benzene which took away the moisture of the flask. Next it was refluxed when a vigorous reaction set in. After half an hour, again zinc (5 g.) and ethyl bromoacetate (2 c.c.) were added

and refluxing was continued for 2 hours. Another lot of zinc (5 g.) was added and heating continued for  $3\frac{1}{2}$  hours. The Reformatsky's reaction complex was decomposed by shaking with acetic acid (11 c.c.) and ethanol (10 c.c.). The reaction product was taken in ether and washed with cold alkali. The ether was driven off and the residue after drying under vacuum was taken in dry ether (20 c.c.) and pyridine (3 c.c.). The above solution, cooled in ice-water, was slowly treated with thionyl chloride (3 c.c.). The reaction mixture was allowed to stand overnight, decomposed with iced hydrochloric acid, washed with dilute bicarbonate solution and distilled, b.p.  $200-5^{\circ}/3.5$  mm., yield 1.7 g. (Found : C, 68.1 ; H, 9.0.  $C_{24}H_{38}O_6$  requires C. 68.24 ; H, 9.0 per cent).

The above unsaturated ester in acetic acid solution was hydrogenated over Adam's catalyst. The absorption of hydrogen was very slow. After the absorption was complete, the catalyst was filtered and the solution was distilled, b.p.  $205^{\circ}/4.5$  mm.

The author's grateful thanks are due to Prof. P. C. Mitter and Prof. D. K. Banerjee for their valuable advice and encouragement during the course of this investigation. Thanks are also due to Mr. N. Ghosh, M. Sc. for micro-analysis of some of the compounds.

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## NATURAL COUMARINS ISOLATED FROM THE LEAVES OF *CITRUS ACIDA*, ROXB.

BY HARINARYAN KHASTAGIR

Three natural coumarins, namely *isopimpinellin*, *bergapten* and *citropten* have been isolated from the leaves of *Citrus acida* var. *medica*. This is for the first time that *isopimpinellin* has been isolated from a *Citrus* species.

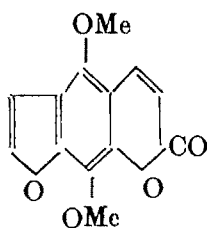
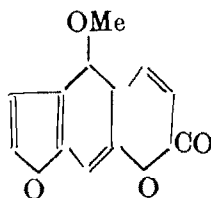
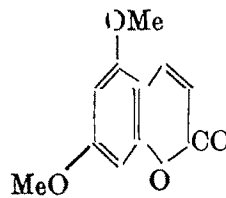
*Citrus acida*, Roxb., the common *Citrus* species of India, is a variety of *Citrus medica* (*Iconum Botanicarum*, *Index Londinensis*, 1930, 2, 224, 255). It is highly valued in therapeutics for its antiscorbutic properties and for curing various intestinal complaints and ailments. The leaves yield a carminative oil which possesses a sweet aroma.

The isolation and the identification of three crystalline constituents have been described in the present communication. The method of purification consists of twenty times fractional sublimations of the crude material in high vacuum, followed by fractional crystallisations from suitable solvents and finally by hand-picking. All the three constituents are neutral towards litmus.

One of the substances melts at 149-50° (yield 0.0095%) and is crystallised from alcohol and ethyl acetate in pale yellow, shining needles. It is readily soluble in ether, fairly in alcohol, ethyl acetate and benzene and insoluble in petroleum ether and water. An alcoholic solution of the substance does not produce any coloration with ferric chloride. It gives an orange-red colour with cold, concentrated sulphuric acid. The substance is insoluble in 1% aqueous alkali but dissolves in alcoholic potassium hydroxide from which the original substance can be precipitated on acidification with mineral acids.

The analytical data of the compound are found to agree with the formula  $C_{11}H_4O_3(OCH_3)_2$ . The properties of the substance, as also the observed analytical values, suggest its identity with those of *isopimpinellin* (I) which has been isolated so far from three different sources, namely, *Pimpinella saxifraga* (Späth and Veerhapper, *Ber.*, 1937, 70, 248), *Luvanga Scandens* (Späth, Bose, Schmid, Dobrovolny and Mookerjee, *Ber.*, 1940, 73, 1361), *Ferula alliaceae* (Bose and Chaudhuri, *Ann. Biochem. Expt. Med.*, 1946, 6, 1). A direct comparison has been made between the two substances, an authentic specimen of *isopimpinellin* was kindly supplied by late Prof. E. Späth of Vienna. The properties of the two compounds are identical and a mixture of the two melted at 150°.

Thus the identity of the first neutral compound with *isopimpinellin* has been established. No alkaloid could be traced in the leaves.

(I) *isoPimpinellin*.(II) *Bergapten*.(III) *Citropten*.

The second constituent forms slender, silky needles, m.p. 187°-88° (yield 0.005%). It develops an orange-red colour with concentrated sulphuric acid. From the properties and behaviour the substance appears to be a coumarin.

The molecular formula of the substance, on analysis, is found to be  $C_{12}H_8O_4$ . It contains one methoxy group as tested by the method of Zeisel-Pregl-Vieböck (*Ber.*, 1930, 63, 2818, 3207). The molecular formula and the properties indicate its identity with *bergapten* (II) which could be established by direct comparison with a specimen of *bergapten* isolated from the leaves of *Skimia laureola* (Späth, *Ber.*, 1937, 60, 114).

The third neutral crystalline principle of *C. acida* crystallises from alcohol in heavy, colourless rods, m.p. 150° (yield 0.0175%).

The C—H values show that the compound has the formula  $C_{11}H_{10}O_4$ . It contains two methoxy groups. The properties of the substance resemble those of *citropten* (III), 5 : 7-dimethoxycoumarin with which the molecular formula of the third substance is the same. A direct comparison of the third constituent could, however, be made with an authentic sample of *citropten* which was obtained from Dr. P. K. Bose to whom the author's best thanks are due.

## EXPERIMENTAL

*Extraction of C. Acida leaves*.—Crushed leaves (air-dried, 2 kg.) of *C. acida* were extracted with ether (4 litres) for 48 hours in a Soxhlet apparatus. The deep green ethereal extract was concentrated to 250 c.c. and kept in a frigidaire for four weeks when a pale yellow solid (A : 0.89g., m.p. 60°-108°) separated. It was collected, washed with a mixture of ether and petroleum ether and dried. The mother-liquor (M) was carefully freed from the solvent and worked up further for coumarins by the method of Späth and Socias, thus :

The oil was cooled to about 15° and to it were added 100 c.c. of 20% methyl alcoholic potassium hydroxide with constant shaking. The mixture was allowed to stand for 45 minutes at the same temperature and then poured into 500 c.c. of ice-water. The mixture was then extracted with ether (250 c.c., in 5 instalments). The red aqueous alkaline solution was acidified with hydrochloric acid (congo red) and allowed to stand overnight. Next morning the greater portion of methyl alcohol was removed under reduced pressure, then cooled and thrice extracted with ether. The yellow ethereal digest was dried over anhydrous sodium sulphate and distilled. The residue was kept in the frigidaire for a week. The residue solidified to a pale yellow solid (B: yield 1.5 g., m.p. 50°-110°). It was washed with petroleum ether to remove adherent oil.

*Isolation of isoPimpinellin from Fractions (A) and (B).*—The fractions A and B (*vide supra*) were mixed together and crystallised successively from ethyl acetate, methyl alcohol and acetone when pale yellow needles (P), m.p. 147-49° separated. The residue obtained from the mother-liquor on crystallisation from various solvents gave a product of m.p. 115-160°. This was subjected to fractional sublimation in high vacuum twenty times when three sublimates in a fairly pure state could be obtained. Fraction (C) subliming at 115-120°/0.1 mm., fraction (D) at 150-55°/0.1 mm., and fraction (E) at 165-170°/0.1 mm.

*Isolation of isoPimpinellin from the Fractions P and C.*—The fractions P and C were crystallised from ethyl acetate when a yellow globular mass, mixed with colourless needles of m.p. 174-76°, separated. The colourless needles (F) were separated from the yellow globular mass by hand-picking. The yellow substance (0.0955 g.) was crystallised thrice from methyl alcohol when glistening yellow needles, m.p. 149-50°, were obtained. Recrystallisation from alcohol and benzene did not raise the m.p. [Found in a sample dried in *vacuo* over  $P_2O_5$  for 4 hours at 100-105°: C, 62.97; H, 3.98; OMe, 24.9.  $C_{11}H_4O_3(OCH_3)$  requires C, 63.4; H, 4.05; OMe, 25.2 per cent]. Mixed with a specimen of pure *isopimpinellin* it showed no depression in m.p.

*Isolation of Bergapten from the Fractions D and F.*—The fractions D and F (*vide supra*) were mixed and crystallised from methyl alcohol. Colourless needles (0.05 g.) separated along with a slimy magma. The slimy matters being lighter could be readily removed from the solution, the needles collecting at the bottom of the crystallising vessel. On recrystallisation from methyl alcohol and ethyl acetate the needles could be obtained pure. The silky, colourless crystals melted at 186-88°. Further crystallisations did not change the m.p. [Found in a sample dried in *vacuo* over  $P_2O_5$  for 4 hours at 100°: C, 66.48; H, 3.67; OMe, 14.5.  $C_{11}H_5O_3(OCH_3)$  requires C, 66.66; H, 3.70; OMe, 14.35 per cent]. The substance showed no change in melting point when mixed with an authentic sample of bergapten having m.p. 188°.

1 *Isolation of Citropten from the Fraction (E).*—The fraction E (*vide supra*, m.p. 145-50°, yield, 0.175 g.) was subjected to repeated crystallisations from methyl

alcohol when heavy, colourless rods of m.p.  $150^{\circ}$  separated out. On further crystallisations the m.p. did not change. [Found in a sample dried in *vacuo* over  $P_2O_5$  for 4 hours at  $100^{\circ}$ : C, 64.4; H, 4.8; OMe, 29.8.  $C_9H_4O_2(OCH_3)_2$  requires C, 64.07; H, 4.8; OMe, 30.09 per cent] When mixed with citropten, m.p.  $150^{\circ}$ , the sample showed no depression in m.p.

In conclusion the author expresses his thanks to Dr. (Mrs). A. Chatterjee for his keen interest and to Mr N. Ghosh for microanalysis.

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## SYNTHETICAL EXPERIMENTS IN STEROLS AND BILE ACIDS

BY SAILENDRA MOHON MUKHERJEE

2-Methyl-3*sec*-isooctylcyclopentanone, an expected intermediate in the synthesis of Wieland's tricarboxylic acid and the sterols, has been synthesised.

To supply the final proof of the exact location of the long chain and to determine the nature of the locking of CD rings in the formulae accepted for the sterols and bile acids, the synthesis of the tricarboxylic acid (XVIII) (Wieland *et al.*, *Z. physiol. Chem.*, 1920, 108, 295; 1933, 216, 91; 1924, 134, 276; 1928, 177, 68) is imperatively necessary. With this end in view an attempt has been made to effect an actual synthesis of the acid (XVIII) with the secondary and tertiary carboxyl groups in their particular stereochemical configuration. A series of unsuccessful or incomplete attempts towards the same end has been recorded in literature (Baker, *J. Chem. Soc.* 1931, 1546; 1933, 811, 815; Bardhan and Banerji, *Science & Culture*, 1937, 2, 654; Benarjee, *ibid.*, 1938, 3, 678; Dutt, *J. Indian Chem. Soc.*, 1942, 19, 79).

Experiments were first begun with a view to preparing the ketone (XIII) which was expected to serve as an intermediate for synthetical purposes in two directions: firstly, the synthesis of Wieland's tricarboxylic acid (XVIII) and secondly, building up of the sterol structure according to the method adumbrated by Robinson, McQuillin and du Fau (*J. Chem. Soc.*, 1937, 53). The previous attempts, which have been made towards the synthesis of this ketone (XIII), are due to Robinson and Peak (*ibid.*, 1937, 1585), and Rydon (*ibid.*, 1939, 1544).

The present method, adopted for the preparation of the acid (III), is altogether different from that devised by Robinson and Peak (*loc. cit.*). It starts from 6-methyl-2-iodoheptane (I), prepared according to Clark (*J. Amer. Chem. Soc.*, 1909, 31, 111) with the only modification of reducing the methyl isohexyl ketone by sodium and moist ether, rectified spirit being added to the reaction mixture in order to minimise the formation of the corresponding pinacol (cf. *Bull. soc. chim. Romania*, 1933, 14, 65). The iodide is converted in moderately good yield to the nitrile (II) by the usual procedure. Hydrolysis of the nitrile (II) presented considerable difficulties. Heating with 15% alcoholic caustic potash does not give satisfactory results. A 60% yield of the acid (III) is obtained by boiling the nitrile with 30% alcoholic caustic potash for a long time. The overall yield may be raised to above 80% by repeating the hydrolysis of the neutral fraction left behind. Having experienced the failure of G. M. Robinson's method (*J. Chem. Soc.*, 1925, 175; 1930, 745) when applied to the condensation product of the acid chloride (IV) with ethyl acetosuccinate (cf. Robinson and Peak, *loc. cit.*), attention was diverted towards the method of Nierenstein (*J. Amer. Chem. Soc.*, 1924, 46, 2551), which was exploited by Haberland (*Ber.*, 1939, 72, 1216) in synthesising keto-acids.



The acid chloride (IV) is subjected to a series of reactions following exactly the conditions worked out by Haberland (*loc. cit.*) whereby the bromo-ketone (V) is obtained in excellent yield and its condensation with ethyl sodiomalonate in benzene proceeds smoothly. The hydrolysis of the resulting keto-diester (VI) with concentrated hydrochloric acid presents no difficulty. The ester (VIII) of the keto-acid (VII), prepared by alcohol-sulphuric acid method, on being subjected to Reformatsky's reaction with ethyl  $\alpha$ -bromopropionate and zinc, affords the lactone (IX) in moderately good yield. The lactone ring is opened up with PBr<sub>3</sub> and ethyl alcohol. The resulting bromo-ester (X) in the crude state is then reduced with zinc dust and acetic acid according to the standard method giving rise to the adipic ester system (XI), which on ring-closure with molecularised sodium in benzene gives the cyclic  $\beta$ -ketonic ester (XII) imparting a greenish violet colour to ferric chloride solution in alcohol. The ketone (XIII) is then obtained by hydrolysing the above  $\beta$ -ketonic ester (XII) with 20% sulphuric acid. The ketone (XIII), thus obtained, characterised by its semicarbazone, has camphoraceous odour.

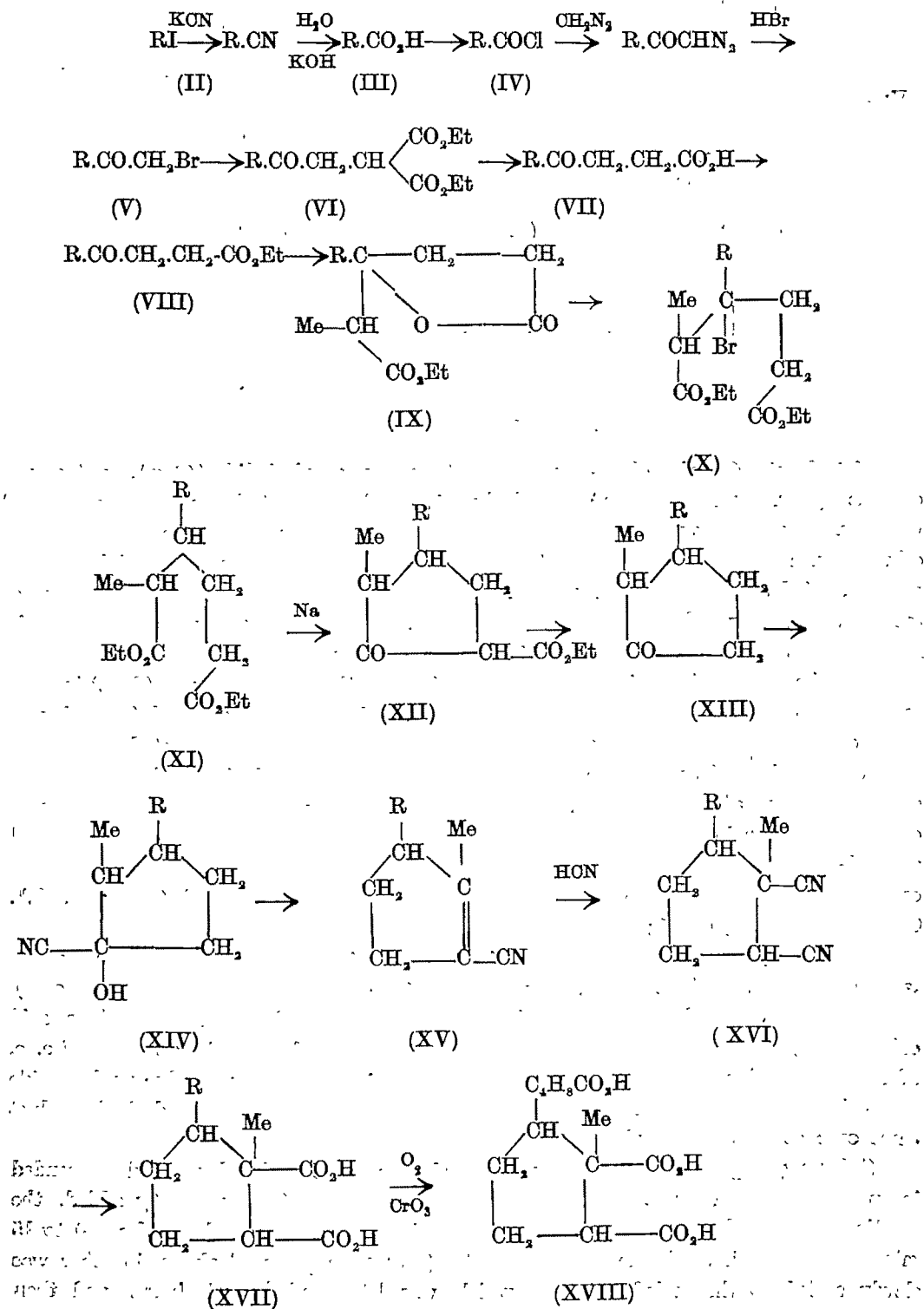
Before proceeding further with this costly material, it was thought desirable to perform some pilot experiments with the easily available 2-methylcyclopentanone (XIII, R=H) in order to find out the exact conditions for the actual synthesis.

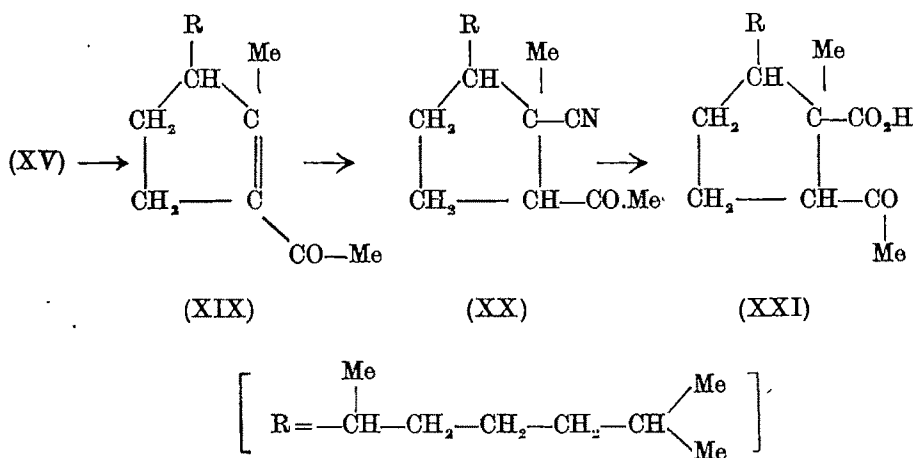
The cyanohydrin of 2-methylcyclopentanone (XIII; R=H) has been prepared according to Clemo, *J. Chem. Soc.*, 1928, 2629, but the yield is not uniform. Robinson and King (*ibid.*, 1941, 467) have reported a better method for the preparation of methylcyclopentanone cyanohydrin. The cyanohydrin (XIV; R=H) on being treated with thionyl chloride and pyridine (*cf.* Robinson and King, *loc. cit.*) is converted into the unsaturated nitrile (XV; R=H) in good yield. The next step, namely, the addition of hydrocyanic acid at the double bond in the unsaturated nitrile (XV; R=H), could not be realised, many attempts under various conditions turning out to be futile.

Again, 2-methyl- $\Delta^1$ -cyclopentene-1-nitrile (XV; R=H) has been converted into 2-methyl-1-acetyl- $\Delta^1$ -cyclopentene (XIX; R=H) by means of the Grignard reagent from methyl iodide according to the conditions of Butenandt and Schmidt-Thomé (*Ber.*, 1938, 71, 1487). Several unsuccessful attempts were made to add hydrocyanic acid to this unsaturated ketone under different conditions ("Organic Synthesis," 1930, Vol. X, p. 50; Lapworth, *J. Chem. Soc.*, 1904, 88, 1219; Newmann, *J. Amer. Chem. Soc.*, 1938, 63, 2949).

Owing to the apparent similarity between Michael addition and hydrocyanic acid addition it was expected that the dicarboxylic acid (XVIII), which would have been obtained through HCN addition to the  $\alpha\beta$ -unsaturated nitrile (XV) or the  $\alpha\beta$ -unsaturated ketone (XIX), should have its carboxylic groups in *trans* configuration in keeping with the expected configuration of the secondary and tertiary carboxyl groups in the tricarboxylic acid (XVIII) obtained from natural sources (*cf.* Linstead and Cook, *J. Chem. Soc.*, 1924, 958). On the other hand, if the *cis*-acid were produced, the *trans*-form could have been obtained by treatment of the *cis*-variety with sodium ethoxide (Bachmann and Struve, *J. Amer. Chem. Soc.*, 1941, 63, 1262 Huckel and Goth, *Ber.*, 1925, 58, 447).

The present scheme of work may be represented thus :—





## EXPERIMENTAL

*Methylheptyl Cyanide* (II).—A mixture of methylheptyl iodide (40 g.), potassium cyanide (22 g.), water (35 c.c.) and alcohol (115 c.c.) was heated under reflux on the water-bath for 12 hours, when the solution assumed a deep red colour. Next it was diluted with water and the light oil extracted with ether. The ethereal layer was washed, dried and the solvent removed. The residue when distilled passed over as a mobile liquid, b. p. 64-66°/6.5 mm., yield 17 g. Owing to the invariable contamination of this sample with the iodide it was not analysed.

*2:6-Dimethylheptoic Acid* (III).—A solution of the above nitrile (70 g.) in 30% methanolic caustic potash (56 g. KOH in 145 c. c. MeOH) was refluxed for 36 hours. Most of the alcohol was then driven off, diluted with water and extracted with ether. The evaporation of ether from the extract gave unhydrolysed nitrile which was again subjected to the above treatment. The alkaline mother-liquor was acidified with cold dilute sulphuric acid and the light oil extracted with ether, the ethereal layer washed and dried ( $\text{Na}_2\text{SO}_4$ ). The solvent was then driven off and the residue when distilled came over at 108°/5.5 mm. as a clear mobile oil, yield 46 g. (Found: C, 67.88; H, 11.1.  $\text{C}_9\text{H}_{18}\text{O}_2$  requires C, 68.35; H, 11.39 per cent).

The amide, prepared by the interaction of the acid chloride and liquor ammonia, when crystallised, had m. p. 97°. (Found: N, 8.86.  $\text{C}_9\text{H}_{19}\text{ON}$  requires N, 8.9 per cent).

*Attempted Synthesis of the Keto-acid* (VII) by *G. M. Robinson's Method*.—The acid chloride (IV) was prepared by treatment of the above acid (III, 40 g.) with 27 c. c. of thionyl chloride and the mixture let stand overnight. The excess of thionyl chloride was driven off in the water pump and the residue distilled when the desired product came over at 74°/5 mm., yield 38 g.

Sodium (25 g.) was granulated under xylene, washed with ether, and suspended in anhydrous ether (120 c. c.) and ethyl acetosuccinate (21.8 g.) gradually added, the solution of the sodium being completed by heating on the water-bath for 10 to 15 minutes. A solution of the acid chloride (15 g.), as prepared above, in ether was slowly added to the cooled mixture which was let stand for 24 hours and then

refluxed for 10 minutes. Then the product was isolated in the usual way and agitated for 5 hours with aqueous potassium hydroxide (1200 c. c. of 4% solution). After acidification with acetic acid and isolation by means of ether, it was submitted to the action of boiling 5% sulphuric acid for 4 hours, and the hydrolysis was completed by boiling with 8% sodium hydroxide solution for 1 hour. The solution was then acidified with dilute sulphuric acid and extracted with ether, the ethereal layer washed and dried ( $\text{Na}_2\text{SO}_4$ ). The residue, left after the removal of the solvent, gave on distillation in vacuum 12 g. of the original acid (2:6-dimethylheptoic acid, III) passing over at  $106^\circ/5$  mm. leaving no significant higher boiling residue.

*$\omega$ -Bromomethyl-sec-isooctyl-ketone (V).*—The above acid chloride (IV, 38 g.) in 25 c. c. of ether was added with cooling to a solution of diazomethane in dry ether (500 c. c.). After standing in the cold for one hour, hydrobromic acid (50 c. c. of 48%), was slowly added in the cold with shaking when a vigorous evolution of nitrogen took place and the mixture was kept overnight. The ethereal solution was then taken up, washed with sodium carbonate solution, water, dried and the solvent driven off. The residue on distillation gave the bromo-ketone, b. p.  $95^\circ/5$  mm., yield 50.5 g. (Found: Br, 33.68.  $\text{C}_{10}\text{H}_{19}\text{OBr}$  requires Br, 34.04 per cent).

*Condensation of Bromo-ketone (V) with Ethyl Sodiomalonate.*—To pulverised sodium (5.5 g.), taken under benzene and cooled in ice was added diethyl malonate (55 g.) and the mixture was left overnight. The bromo-ketone (V, 50 g.) was then slowly added with cooling and left for 1 hour. After refluxing for 16 hours on the water-bath, the mixture was cooled and water added, the benzene layer washed and dried. The residue, left after the evaporation of the solvent, gave the malonic ester derivative (VI, 56 g.), b. p.  $168^\circ/5$  mm. (Found: C, 64.72; H, 9.53.  $\text{C}_{17}\text{H}_{30}\text{O}_5$  requires C, 64.97; H, 9.55 per cent).

*$\delta$ -isohexylhomolaevulinic Acid (VII).*—The above malonic ester derivative (VI, 58 g.) was refluxed with 250 c. c. of dilute hydrochloric acid (1:1) for 24 hours. The cooled mixture was then extracted with ether and the ethereal extract washed twice with sodium carbonate solution. From the ethereal solution 4 g. of the unchanged malonic ester derivative were recovered. The sodium carbonate extract was acidified with cold dilute sulphuric acid, extracted with ether and the ethereal layer washed and dried. After the evaporation of the solvent the residue was distilled in *vacuo* when a sweet-smelling, thick liquid (32 g.) came over at  $150^\circ/3$  mm. (Found: C, 67.16; H, 10.22.  $\text{C}_{12}\text{H}_{22}\text{O}_3$  requires C, 67.29; H, 10.28 per cent).

The ester (VIII) of the above acid was prepared by refluxing a mixture of the keto-acid (32 g.), absolute alcohol (100 c. c.) and concentrated sulphuric acid (*d* 1.84; 6 c. c.) for 16 hours. After the usual working up, the ester was distilled in *vacuo*, b. p.  $122^\circ/2$  mm., yield 32.5 g. (Found: C, 69.14; H, 10.62.  $\text{C}_{14}\text{H}_{26}\text{O}_3$  requires C, 69.42; H, 10.74 per cent).

*Reformatsky's Reaction between the above Keto-ester (VIII) and Ethyl  $\alpha$ -Bromopropionate.*—A mixture of 24 g. of the above keto-ester (VIII), 9 c. c. of ethyl  $\alpha$ -bromopropionate, 13 g. of zinc wool (washed with dilute hydrochloric acid, water, acetone and dried before use), 5 c. c. of thiophen-free benzene and 0.5 g. of iodine was heated under reflux on the water-bath. Within 10 to 15 minutes, the violet colour disappeared

and the solution became turbid. A violent reaction then ensued. The reaction sometimes became so violent that heating was temporarily stopped. After the abatement of the vigour of the reaction refluxing was continued for 1 hour, after which a fresh addition of 13 g. of zinc (activated) and 9 c. c. of ethyl  $\alpha$ -bromopropionate and a few crystals of iodine was made and refluxing continued for 2 hours more when the reaction mixture assumed a greenish brown colour and a brown-coloured zinc complex was deposited at the bottom. The cooled reaction mixture was decomposed with acetic acid and methyl alcohol and diluted with water. The solution was then extracted with ether and the ether-benzene extract washed with dilute ammonia until the alkaline washings ceased to be coloured. After washing with water, the extract was dried, the solvents removed and the residue distilled when 16 g. of the lactone (IX) was obtained, b. p.  $170^{\circ}/4$  mm. (Found: C, 68.18; H, 9.8.  $C_{17}H_{30}O_4$  requires C, 68.45; H, 10.06 per cent).

*Diethyl  $\alpha$ -Methyl- $\beta$ -sec.-isooctyladipate* (XI).—The above lactone (15 g.) was treated gradually with  $PBr_3$  (25 g.) when the mixture assumed a deep red colour. The reaction mixture was kept overnight at the room temperature, the whole of the phosphorus pentabromide going into solution by that time. The dark red solution was poured into 50 c. c. of absolute alcohol, well cooled in ice. The solution was then refluxed on the water-bath for half-an-hour, cooled and poured into cooled water, the heavy layer extracted with ether, the ethereal extract washed with sodium bicarbonate solution, water, and dried. The residue left after the evaporation of the solvent was dried in vacuum and was dissolved in 150 c. c. glacial acetic acid and to this was added during 1 hour 32 g. of zinc dust, when the solution became rather hot. The mixture was then heated under reflux on a sand-bath for 20 hours. After decanting from the zinc sludge, the acetic acid solution was treated with ice-cooled caustic soda solution to neutralise most of the acetic acid, the solution diluted with water, and extracted with ether, the ether extract washed and dried. After the evaporation of the solvent, the residue on distillation in *vacuo* gave a halogen-free material (10.5 g.), b. p.  $175^{\circ}/6$  mm. (Found: C, 69.26; H, 10.68.  $C_{16}H_{30}O_4$  requires C, 69.51; H, 10.97 per cent).

*Ethyl 2-Methyl-3-sec.-isooctylcyclopentane-5-carboxylate* (XII).—A mixture of 10 g. of the above dicarboxylic ester (XI), 1.5 g. of sodium and 30 c. c. of dry benzene was refluxed on the water-bath. After the whole of the sodium had gone into solution (1-1½ hours) the refluxing was continued for further half an hour. The solution assumed a red colour and after cooling it was decomposed with ice-cold dilute sulphuric acid and extracted with ether. The ethereal extract was washed with dilute sodium carbonate solution, water and dried. The sodium carbonate extract was acidified and the separated oil collected. The evaporation of the solvent from the dried ethereal extract afforded 5.6 g. of the  $\beta$ -keto-ester with positive ferric reaction, b. p.  $145^{\circ}/5$  mm. (Found: C, 72.65; H, 10.56.  $C_{17}H_{30}O_3$  requires C, 72.34; H, 10.63 per cent).

*2-Methyl 3-sec.-isooctylcyclopentanone* (XIII).—The above keto-ester (XII, 5.6 g.) together with the oil obtained by acidification of the sodium carbonate extract (see the previous experiment) was refluxed with hydrochloric acid (50 c. c., conc.) for 24 hours. The cooled solution was then extracted with ether, the ethereal layer washed and dried ( $CaCl_2$ ).

After driving off the solvent the residue gave on distillation in *vacuo* 3 g. of the desired ketone, b. p.  $122^{\circ}/8$  mm. having a camphoraceous odour. (Found: C, 79.62; H, 12.36.  $C_{14}H_{24}O$  requires C, 80.0; H, 12.38 per cent).

The *semicarbazone*, prepared in the usual way, was crystallised from aqueous ethyl alcohol, m. p.  $180-81^{\circ}$ . (Found: N, 15.91.  $C_{14}H_{24}ON_3$  requires N, 15.73 per cent).

**2-Methyl- $\Delta^1$ -cyclopentene-1-nitrile** (XV; R=H).—To an ice-cold mixture of 2-methylcyclopentanone cyanohydrin (XIV, R=H 25 g.), prepared according to the method of Clemo (*loc. cit.*) and pyridine (32 c.c.) thionyl chloride (30 c.c.) was slowly added with shaking. After an hour the reaction mixture was heated on the steam-bath for 2 hours and cooled and decomposed with ice and hydrochloric acid. After ether extraction, washing with dilute hydrochloric acid and water, the solvent was removed. The unsaturated nitrile (18 g.), b. p.  $76-78^{\circ}/20$  mm., thus obtained, contained much dissolved sulphur which was removed by heating the nitrile in 50 c.c. of benzene with 2 g. of precipitated copper for an hour. After the usual procedure the nitrile came over on distillation as a clear, mobile liquid.

**Attempted Hydrocyanic Acid Addition to the Nitrile** (XV; R=H).—Potassium cyanide (28.7 g.) was dissolved in 95% alcohol (50 c.c.) and the solution cooled to room temperature. To this was added 15 g. of the nitrile (XV; R=H) and the solution was heated on the water-bath for half an hour. The cooled solution was largely diluted with water, extracted with ether, the ethereal layer washed twice with water and dried. After removing the solvent, the residue came over at  $80-82^{\circ}/24$  mm. leaving no appreciable high boiling residue.

**2-Methyl-1-acetyl- $\Delta^1$ -cyclopentene** (XIX; R=H).—The above unsaturated nitrile (XV; R=H, 15 g.) was added dropwise to a Grignard solution (3.5 g. of Mg. and 12 c.c. of MeI in 50 c.c. dry ether). The ether was driven off, dry thiophen-free benzene (50 c.c.) was added and the mixture refluxed for 6 hours. To the cooled reaction mixture was then added acetic acid (15 c.c.) and heating continued for half an hour. Water was then added and the mixture heated for further half an hour. The benzene layer was taken up, washed with water twice, dried and after the evaporation of the solvent the residue was distilled, when a clear liquid (12 g.) came over at  $103^{\circ}/5$  mm. (Found: C, 76.93; H, 9.8.  $C_8H_{12}O$  requires C, 77.42; H, 9.67 per cent).

The *semicarbazone*, prepared in the usual way, was crystallised from aqueous methyl alcohol, m. p.  $200-201^{\circ}$ . (Found: N, 23.3.  $C_8H_{12}ON_3$  requires N, 23.2 per cent).

**Attempted Hydrocyanic Acid Addition to the Unsaturated Ketone** (XIX; R=H).—

(a). According to the conditions of Lapworth (*loc. cit.*) a solution of the above ketone (12 g.) in 75 c.c. of boiling alcohol was mixed with a solution of potassium cyanide (13 g.) in 40 c.c. of hot water and the whole heated on the water-bath for 15 minutes. To the cooled mixture was added an aqueous solution of 5 g. of ferrous sulphate which served the purpose of converting the excess of potassium cyanide into ferricyanide as well as decomposing any cyanohydrin formed. The latter process was completed by raising the whole once more to the boiling point with constant shaking, care being taken that the liquid remained alkaline throughout. After filtration the liquid was diluted with water, extracted with ether, the ethereal extract dried and evaporated. The residue on distillation in vacuum was found to consist entirely of the unchanged ketone.

(b). According to the condition of Newmann (*loc. cit.*) a solution of 16.5 g. of potassium cyanide in 30 c. c. of water was added under the surface to a solution, at 55°, of 12.5 g. of the ketone (XIX; R=H) in 108 c. c. of alcohol. The addition was made over a period of 5 minutes with continued shaking. After 5 minutes the contents were warmed to 60°, the flask was wrapped with several towels and allowed to stand undisturbed for 1½ hours. After cooling, the solution was diluted with water, extracted with ether, the ethereal layer washed and dried. After the evaporation of the solvent the residue was distilled in vacuum when nothing except the unchanged ketone came over.

The author's grateful thanks are due to Prof. P. C. Mitter for his valuable advice and encouragement during the course of these investigations. The thanks are also due to Mr. N. Ghosh and Dr. B. K. Bhattacharyya for micro-analysis of some of the compounds.

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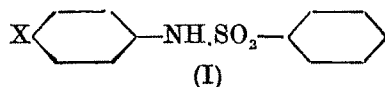
# ORGANO-ARSENICALS. PART III. SULPHANILAMIDO- N<sup>1</sup>-PHENYLARSONIC ACIDS\*

BY PALLAVUR PARASURAMIYER KRISHNAN, BALKRISHNA HARITHAR IYER  
AND PRAPHULLA CHANDRA GUHA

The action of *p*-acetaminobenzene sulphonylchloride on *o*-, *m*- and *p*-aminophenylarsonic acids as well as on 4-amino-3-methylphenylarsonic acid has been studied.

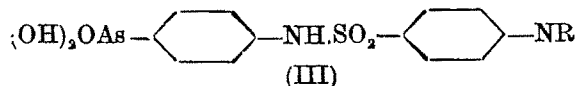
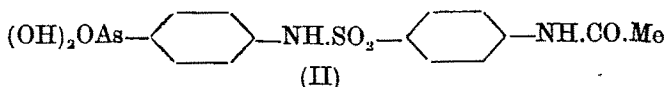
*p*-Arsanilic acid is the parent substance of a number of therapeutically active organo-arsenicals. Since Ehrlich's discovery of the trypanocidal activity of atoxyl, a large number of organo-arsenicals have been synthesised and tested.

4-Phenylsulphonamidophenylarsonic acid [I, X=As (OH)<sub>2</sub>] has been prepared from 4-phenylsulphonamido-aniline (I, X=NH<sub>2</sub>) by Mouneyart's modification (Eng. Pat., 142947 of 1919) of Bart's method for replacing NH<sub>2</sub> group by AsO(OH)<sub>2</sub> group. Compound (I) has also been prepared by the condensation of benzene sulphonyl chloride with *p*-arsanilic acid in presence of alkali or alkali carbonate (Mouneyart, F.P. 401586 of 1906).



The present investigation was undertaken with a view to preparing and making a systematic study of compounds having in their molecules a combination of arsonic acid and sulphonamido groups.

*p*-Acetaminobenzene sulphonylchloride, when reacted with *p*-arsanilic acid in presence of anhydrous sodium carbonate, N<sup>4</sup>-acetylsulphanilamido-N<sup>1</sup>-phenyl-4'-arsonic acid (II) results. The reaction was tried under varying conditions *viz.*, (i) by dissolving the reactants in a solvent like alcohol, benzene or chloroform; (ii) in presence of alcoholic caustic soda; (iii) in presence of sodium ethylate, sodamide, dimethylaniline, pyridine, sodium carbonate and sodium bicarbonate; and (iv) by fusion of the two reactants. Of all these methods, the one using the sodium salt of the arsonic acid has been found to be successful.



The sodium and barium salts of (II) have been prepared. Compound (II) on hydrolysis with hydrochloric acid yields sulphanilamido-N<sup>1</sup>-phenyl-4'-arsonic acid (III, R=H<sub>2</sub>).

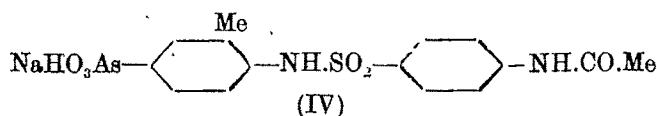
\* A note on this work appeared in *Science and Culture*, 1945-46 11, 565.



While its sodium and barium salts are quite stable, the potassium salt decomposes on keeping. Compound (III,  $R=H_2$ ) has been condensed with benzaldehyde and *p*-dimethylaminobenzaldehyde to give *N*<sup>4</sup>-benzylidene-sulphanilamido-*N*<sup>1</sup>-phenyl-4'-arsonic acid (III,  $R=CH_2Ph$ ) and *N*<sup>4</sup>-*p*-dimethylaminobenzylidene-sulphanil-amido-*N*<sup>1</sup>-phenyl-4'-arsonic acid [III,  $R=CH_2C_6H_4NMe_2$  (*p*)] respectively. Although Northey (*Chem. Rev.*, 1940, 27, 99) has referred to compound (III,  $R=H_2$ ) from personal communications, no details seem to have been published.

Attempts to isolate pure products from the condensation of *o*- and *m*-aminophenyl-arsonic acids with *p*-acetaminobenzene sulphonylchloride were unsuccessful.

The action of 4-amino-3-methylphenylarsonic acid (Friend, 'Text Book of Inorganic Chemistry', Vol. XI, Part II, p. 224) with *p*-acetaminobenzene sulphonylchloride gives the sodium salt of *N*<sup>4</sup>-acetylsulphanilamido-2'-methylphehyl-4'-arsonic acid (IV).



Its hydrolysed product could not be obtained in a pure form.

## EXPERIMENTAL

*N*<sup>4</sup>-Acetylsulphanilamido-*N*<sup>1</sup>-phenyl-4'-arsonic acid (II).—To a solution of the sodium salt of *p*-arsanilic acid (5.76 g.) in water (24 c.c.) containing anhydrous sodium carbonate (1.25 g.), *p*-acetaminobenzene sulphonylchloride (5.6 g.) was gradually added under stirring. After complete dissolution, the liquid was filtered and acidified with dilute hydrochloric acid. A white semi-solid separated out immediately. The supernatant liquid was decanted off and fresh hydrochloric acid added and allowed to stand for 3 hours. The resulting white powder was collected and purified by dissolution in dilute sodium hydroxide and precipitation with dilute hydrochloric acid, yield 5.8 g. (Found: As, 17.94,  $C_{14}H_{15}O_6N_2SAs$  requires As, 18.11 per cent).

*Sodium salt of (II)*.—Compound (II) was suspended in water and dilute sodium hydroxide solution added drop by drop with shaking till the whole of the substance went into solution. An equal volume of alcohol was then added and the liquid well stirred. The sodium salt first separated as an oil, which on standing changed into white powder. It was filtered, washed with alcohol and dried. (Found: As, 17.03.  $C_{14}H_{14}O_6N_2SAsNa$  requires As, 17.20 per cent).

*Barium Salt of (II)*.—Similarly, the barium salt was prepared using a solution of barium hydroxide instead of sodium hydroxide. [Found: As, 15.36.  $(C_{14}H_{14}O_6N_2SAs)_2Ba$  requires As, 15.57 per cent].

*Sulphanilamide-*N*<sup>1</sup>-phenyl-4'-arsonic Acid (III,  $R=H_2$ )*.—The compound (II, 2 g.) was refluxed with hydrochloric acid (1:1, 10 c.c.) till all the solid went in solution and for a further period of 5 minutes. The liquid was then cooled, made alkaline with ammonia,

filtered and the filtrate acidified with acetic acid when the amino compound separated. It was filtered out, dissolved in alkali and reprecipitated with acetic acid; the product was soluble in hydrochloric acid. (Found: As, 20.0.  $C_{12}H_{13}O_3N_2SAs$  requires As, 20.17 per cent).

*Sodium salt of (III, R=H<sub>2</sub>)* was prepared by dissolving the acid in the requisite amount of aqueous sodium hydroxide and precipitating with alcohol. (Found: As, 18.81.  $C_{12}H_{12}O_3N_2SAsNa$  requires As, 19.04 per cent).

*Barium salt of (III, R=H<sub>2</sub>)* was prepared by dissolving the acid in the requisite quantity of aqueous barium hydroxide and precipitating with alcohol. [Found: As, 16.97.  $(C_{12}H_{12}O_3N_2SAs)_2Ba$  requires As, 17.06 per cent].

*N<sup>4</sup>-Benzylidene-sulphanilamido-N<sup>1</sup>-phenyl-4'-arsonic Acid (III, R=CH.Ph).*—Compound (III, R=H<sub>2</sub>; 2 g.) and benzaldehyde (0.6 g.) were thoroughly mixed in a test-tube and heated in an oil-bath at 140–150° for 2 hours and then the mass was cooled, extracted with sodium hydroxide solution (10%) and filtered. The filtrate on acidification with hydrochloric acid gave a thick precipitate which was collected, washed with a small quantity of water and dried, yield 1.8 g. (Found: As, 16.15.  $C_{19}H_{17}O_3N_2SAs$  requires As, 16.30 per cent).

*N<sup>4</sup>-p-Dimethylaminobenzylidene-sulphanilamido-N<sup>1</sup>-phenyl-4'-arsonic Acid (III, R=CH.C<sub>6</sub>H<sub>4</sub>.NMe<sub>2</sub>).*—Compound (III, R=H<sub>2</sub>; 3.5 g.) was thoroughly mixed with *p*-dimethylaminobenzaldehyde (1.5 g.) and heated in a hard glass test tube in an oil-bath at 140–150° for 3 hours and then the dry mass was extracted with alkali and filtered. The filtrate on acidification deposited a precipitate which was collected, washed with water and dried, yield quantitative. (Found: As, 14.80.  $C_{21}H_{23}O_3N_3SAs$  requires As, 14.91 per cent).

*Sodium Salt of N<sup>4</sup>-Acetylsulphanilamido-2'-methylphenyl-4'-arsonic Acid (IV).*—The sodium salt of 4-amino-3-methylphenylarsonic acid was prepared by dissolving the acid in hot sodium hydroxide solution (25%) and pouring the filtered solution into cold alcohol. The salt separating was collected, washed with alcohol and dried.

To a solution of this salt (2.5 g.) in water (10 c.c.) containing anhydrous sodium carbonate (1.1 g.) *p*-acetaminobenzene sulphonylchloride (2.3 g.) was added in small quantities with shaking. After the reaction was over, it was filtered and the filtrate acidified with hydrochloric acid when the arsonic acid precipitated out. It was collected and converted into its sodium salt by dissolving in the requisite amount of alkali and precipitating with alcohol, yield 2.4 g. (Found: As, 16.49.  $C_{15}H_{16}O_3N_2SAsNa$  requires As, 16.66 per cent).

The sulphanilamidophenylarsonic acids detailed in this paper are insoluble in common organic solvents, have no sharp melting points, and are purified only by repeated precipitation with acid from their solution in alkali.

*Estimation of Arsenic.*—The volumetric methods being easy to operate are suitable for routine analysis and hence these were critically studied. Ewin's method

(*J. Chem. Soc.*, 1916, 109, 1355) was found to give fairly reliable results with the present series of compounds. But the time required for the digestion of the compounds was very long and the considerable frothing, which happened during digestion, made the method rather cumbersome.

Das-Gupta (*J. Indian Chem. Soc.*, 1932, 9, 95) dissolved the pentavalent arsonic acids in concentrated hydrochloric acid with warming and treated the solution with potassium iodide. The liberated iodine was then titrated against standard thiosulphate solution. This method could not, however, be applied for the present series of compounds as the end-point was not at all sharp.

The method developed by Robertson (*J. Amer. Chem. Soc.*, 1921, 43, 182) was used in the present investigation. The end-point was very sharp, the time taken was less than that obtained in other methods and the results were reliable.

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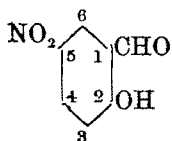
# CONDENSATION OF ALDEHYDES WITH MALONIC ACID. PART XVIII. CONDENSATION OF 5-NITRO-2-HYDROXYBENZALDEHYDE

BY KANTILAL C. PANDYA, OMENDRA SWARUP SAXENA AND  
JESSEL DAVID TINKU

5-Nitro-2-hydroxybenzaldehyde (5-nitrosalicylaldehyde) is condensed with malonic acid. It does not enter into condensation in the absence of any condensing reagent or even in the presence of glacial acetic acid. In the presence of pyridine, piperidine or a mixture of the two, it gives 5-nitro-2-hydroxybenzylidene-malonic (5-nitrosalicylidene-malonic) acid, the highest yield, so far obtained, being 84% in five hours' heating at 80° : as salicylaldehyde has always given much lower yields, the increase could be due only to the influence of the nitro group in 5 position. The corresponding mono-acid has, however, not been obtained yet from either the aldehyde or the dibasic acid.

The influence of several dissimilar groups (situated on the aromatic ring of the aldehyde) on the aldehyde-malonic acid condensation has already formed the subject of some of the papers in this series. For example, the condensation of malonic acid with vanillin (Pandya and Sodhi, *Proc. Ind. Acad. Sci.*, 1939, 9A, 512), where one hydroxy group and one methoxy group occur on the ring ; with 5-bromosalicylaldehyde and with 3:5-dibromosalicylaldehyde (Pandya and Miss Pandya, *ibid*, 1943, 18A, 164) where a hydroxy group in the *ortho* position occurs with one or two bromo groups ; and some more unpublished work in theses (such as by Gauri Shankar Gupta on condensation of 3:5-dibromo-*p*-hydroxybenzaldehyde ; Miss R. Pandya, on that of bromo- and nitropiperonal ; and Raghunath Singh, on those of several halogenated hydroxybenzaldehydes).

The present paper deals with a nitro group and an *ortho*-hydroxy group in 5-nitro-2-hydroxybenzaldehyde (5-nitrosalicylaldehyde). The nitro group could take up, directly or indirectly, any of the four positions- 3, 4, 5 or 6. In position 5, the group



is sufficiently far from both the hydroxy and the aldehyde group and will not introduce any complication due to a hydrogen bond or chelation. The condensation in actual practice goes well and is characterised by several peculiarities.

Firstly, it offers a contrast to benzaldehyde and salicylaldehyde in not entering, under ordinary conditions, into condensation with malonic acid in the absence of any condensing base, or even in the presence of glacial acetic acid alone.

Secondly, in the presence of pyridine, piperidine or a mixture of the two, it gives 5-nitrosalicylidene-malonic acid, a dibasic acid, the analogue of which has so far not been obtained (though 5-bromo- and 3-5-dibromosalicylaldehydes gave similar products, Pandya and Miss Pandya, *loc. cit.*) from salicylaldehyde, and the analogous compound

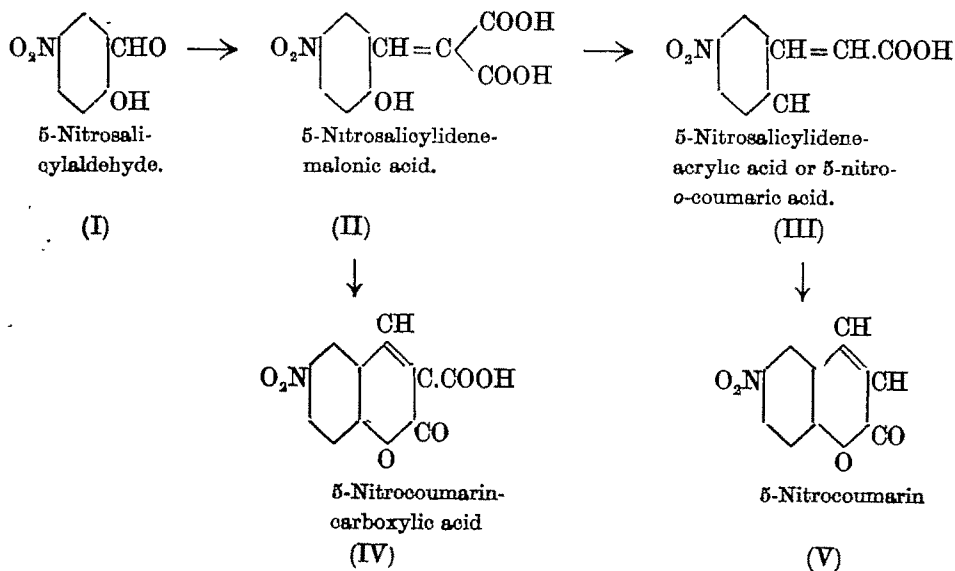
\* A part of the M.Sc. thesis of D.T. (1941) and a part of the M.Sc. thesis of O.S.S (1944), both having worked independently.

from benzaldehyde is obtained by heating with glacial acetic acid (Stuart's method) or heating without any condensing agent (Pandya and Miss Pandya, *loc. cit.*).

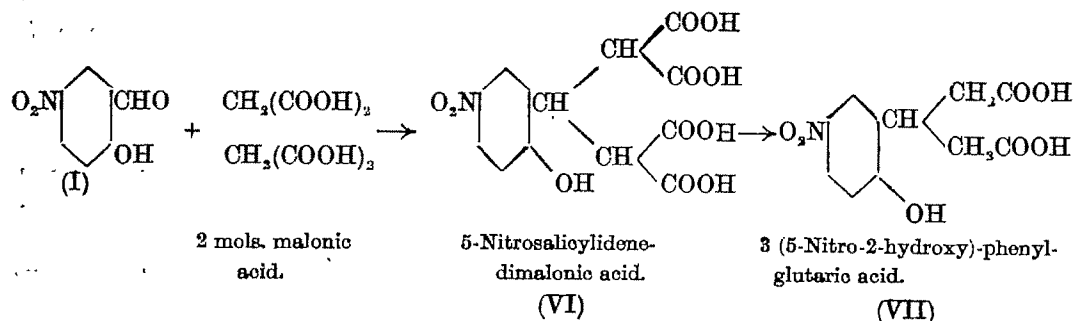
Thirdly, and this seems remarkable, the expected monobasic acid, 5-nitro-2-hydroxycinnamic acid, has not been obtained by any of the methods so far tried. It has not been obtained in a pure condition from the dibasic acid even. Nor was the nitrocoumarin-carboxylic acid obtained.

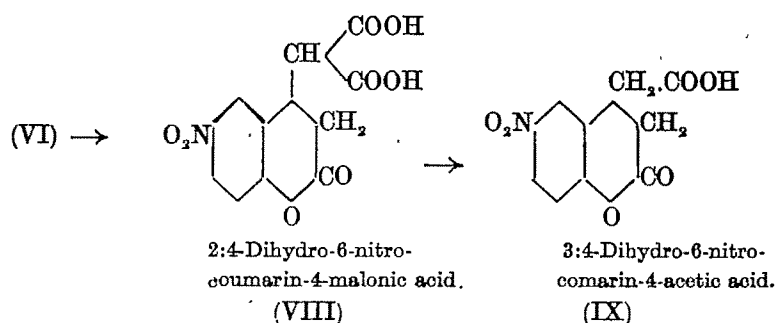
In the case of salicylaldehyde, the usual product has been coumarin carboxylic acid which would be formed only from salicylidene-malonic acid (Kurien and Pandya, *J. Indian Chem. Soc.*, 1934, 11, 824), which has not yet been isolated. Another product has also been isolated now (Ph. D. thesis by Raghunath Singh, unpublished), which is also, quite different. It appears, however, that the presence of the nitro group in position 5 imparts a great stability to this product besides giving an increased yield.

Its identification rests on the equivalent and molecular weight determinations and on the nitrogen content; all of which agree with this structure and rule out other alternatives, which may be as under:—



Three more possibilities are suggested from recent work in this laboratory on salicylaldehyde and its chloro derivatives (unpublished, Raghunath Singh). These are:





Thus there are eight structures that are most likely; a few more could be worked out from the tetracarboxylic acid (VI) by anhydride formation, which, however, may be omitted as being less likely.

1. The product obtained gives a definite melting point which is much lower than that of (III) (which melts at  $245^{\circ}$ ), and definitely higher than that of (V) which melts at  $185^{\circ}$ . So the actual melting point rules out (III) and (V).

2. The product obtained is a distinct acid, and so the nitrocoumarin (V) is again out of question.

3. The product always melts with effervescence, suggesting a dibasic acid of the malonic type. All monobasic acids are thus ruled out, namely (III), (IV) and (IX).

4. The acid gives clear indications of unsaturation: so those structures having no double bond are not indicated, such as (VI), (VII), (VIII) and (IX).

5. The ferric chloride reaction of the phenolic group suggests that a free hydroxy group is present and that there is no coumarin ring, as is involved in presence of (IV), (V), (VIII) and (IX).

6. The equivalent weight found is roughly 129: so all monobasic acids, (III), (IV) and (IX) are again excluded. In fact only (II) and (VI) are left so far. (VI) is a tetracarboxylic acid, which would probably be highly unstable, with a high melting point, and with about 89 as the equivalent weight. (II) on the other hand requires 126.5, and the experimental value is nearest to it. The molecular weight by Rast's method is also agreeable to (II) only, being 255.3; (II) requires 253.

7. Lastly, the nitrogen content agrees very well: (II) requires 5.53% (found 5.50%).

A word is necessary about the yield, which is greater in the ordinary conditions than that obtained from salicylaldehyde. For though the maximum yield of coumarin-carboxylic acid from salicylaldehyde is given as 51% (Kurien and Pandya, *loc.cit.*) and rises even to 77% with the use of special bases (Khan, Kurien and Pandya, *Proc. Ind. Acad. Sci.*, 1935, 1, 443), a recent revision of the condensation employing a pyridine-trace under the ordinary conditions gave only 30% of coumarin-carboxylic acid and 13% of another acid (Raghunath Singh, 1946, unpublished work). In the present case of 5-nitrosalicylaldehyde, the best yields came up to about 80 to 84% as can be seen from the table at the end. It can be thus seen that the nitro group in position

5, has not only given a peculiar stability to a rare condensation product, but has also increased the yield.

#### EXPERIMENTAL

*Preparation of 5-( & 3)-Nitrosalicylaldehydes.*—Salicylaldehyde was nitrated according to Miller (*Ber.*, 1887, 20, 1928) by means of fuming nitric acid at 10°. The orange precipitate that was obtained on adding this mixture to cold water contained both 5-nitro- and 3-nitro-salicylaldehyde. 5-Nitrosalicylaldehyde (m. p. 126°) came out in pale white crystals in 24% yield and the 3-nitrosalicylaldehyde (m. p. 107°) came out in 65% yield. (Mazzara gives the m.p. as 123-25° and 105-107° respectively, *J. Chem. Soc.*, 1877, 1, 597). The total yield was thus 89% when separated; the total yield before separation was 98-100% of theory. The method of separation was the same as given by Miller (*loc cit.*). The preparation was repeated several times, under identical conditions, but relative yields generally varied. Attempts to prepare each one of the nitro derivatives separately in a pure condition did not meet with success.

#### Condensation of 5-Nitrosalicylaldehyde

Perkin's method did not give any condensation product, as claimed by Tage (*Ber.*, 1887, 20, 2109). The dirty yellow product obtained, on the usual treatment, gave back the 5-nitrosalicylaldehyde, which was identified by means of a mixed m.p. with an authentic specimen of the aldehyde, prepared in the laboratory.

*Condensation with Malonic acid but without any reagent.*—The mixture of the 5-nitrosalicylaldehyde (1.7 g.) and malonic acid (1 g.) was heated first on the water-bath and as it did not fuse even after an hour's heating, it was heated on an oil-bath at 105° to 125° for 4 hours, or 12 hours heating up to 140°. No fusion took place and most of the aldehyde was recovered unchanged.

*Condensation by Stuart's method with Glacial Acetic acid as a condensing agent.*—When heated for 6 hours the original aldehyde was recovered (about 87%).

*Condensation with Malonic acid with a Trace of Pyridine.*—(i) The mixture was heated in the usual way (1:1:0.2 mol.) at 100-105° for 4 hours. The reaction started immediately, gas began to come out and a part of the aldehyde sublimed in the neck of the flask. The mass fused, but resolidified in about 45 minutes. Some aldehyde was recovered unchanged, but a pale yellow solid acid product also came out (separated by  $\text{NaHCO}_3$  soln.). The latter was washed with chloroform, and it melted at 195-98°. Recrystallised from a mixture of benzene and alcohol, it melted at 199-201° with effervescence. 3.4 G. of 5-nitrosalicylaldehyde gave 2.5 g. of the acid, and so the yield of the dibasic acid was 49.4%. But as 0.8 g. of the aldehyde was recovered unchanged, the yield was really 61.6% of the total aldehyde used.

(ii) The condensation was repeated at lower temperatures, in order to avoid or reduce the sublimation of the aldehyde. The yield then increased. Thus condensation at 95-98° gave 2.8 g. (55.3%) yield, with 0.7 g. of unused aldehyde; so on the

aldehyde used, the yield was 69.1%. At 90° the yield was 3.1 g. or 61.2%; 0.4 g. of the aldehyde was recovered, therefore on the aldehyde used, the yield was about 80%. At 80°, five hours' heating gave 69.1% yield; deducting 0.3 g. aldehyde recovered, the yield became 84% of theory.

*Condensation with more Pyridine.*—The aldehyde, malonic acid and pyridine were taken in the proportion of 1:1:1 mol. Less pyridine was taken at the start, but the remainder was added to bring down the sublimed crystals of nitrosalicylaldehyde from the neck of the flask. The heating was for 6 hours on the water-bath. The yield was only 41.5%, or deducting the 20% of the aldehyde recovered, it was 49%. With two and three molecules of pyridine and 12 hours' heating on the water-bath, the yields again came up to 67.3% and 69.1% of theory.

*Condensation with Piperidine as a condensing agent.*—With a molecule of piperidine in place of pyridine, and heating for 6 hours on a water-bath, the yield was again low, 43%.

*Condensation by Vorsatz's method with pyridine at room temperature.*—The three ingredients were taken in the proportion of 1:1:10 mols. and kept at room temperature for 3 weeks. The yield was only 17%; still longer time might possibly have raised the yield.

Condensation by Robinson's method with pyridine-piperidine mixture gave an yield of 68.7%.

*Condensation in presence of ether without a catalyst.*—Sufficient ether was taken to make the reactants dissolved. The mixture was kept for 3 weeks: the aldehyde was recovered unchanged. Another flask of the above was kept for 3 months, but no condensation took place.

The product obtained in all the above condensations was identical. It had a bright yellow colour and melted after recrystallisation at 193° with effervescence, suggesting a dibasic acid of the malonic type. It was readily soluble in dilute alcohol, glacial acetic acid, acetone and carbon tetrachloride; sparingly soluble in benzene and ethyl acetate and insoluble in ether and chloroform. It also dissolved in strong sulphuric acid with a red colour. Its alcoholic solution gave with aqueous or alcoholic ferric chloride a deep red colour. It decolorised Baeyer's reagent in the cold. Its solution in glacial acetic acid, even the solid acid alone, decolorised readily bromine water or bromine in acetic acid. [Found: N, 5.76, 5.47, 5.50.  $C_{10}H_7O_7N$  (nitrosalicylidene-malonic acid) requires N, 5.53 per cent].

Equivalent weight determination by titration against standard alkali was found to be impossible as the acid gave an orange or yellow-coloured solution with alkali, making phenolphthalein useless. A rough approximation was 110-120. As the acid gave a yellow silver salt, an average of three estimations gave the equivalent weight as 129 which is slightly higher than the expected value of 126.5.

Molecular weight determinations by Rast's method gave 260 and 255.3;  $C_{10}H_7O_7N$  requires 253.0.

Several different experiments which were made to obtain a monobasic acid from this dibasic acid by different methods failed to give any clear product.



TABLE I

Mol. proportions. Aldhyde	Acid. Catalyst.	Temp.	Heated for.	Yield%	
				taken.	consume .
1 +	AcONa+Ac <sub>2</sub> O (Perkin)	170-180°	8 hr.	0.0	0.0
1 : 1 : 1	glacial AcOH (Stuart)	120°	6	0.0	0.0
1 : 1 : 0.0		100-140°	12	0.0	0.0
1 : 1 : 0.2	Pyridine	100-105°	4	49.4	61.4
1 : 1 : 0.2	"	95-98°	4	55.3	69.1
1 : 1 : 0.2	"	90°	4	61.2	80
1 : 1 : 0.2	"	80°	5	69.1	84
1 : 1 : 1	"	98-99°	6	41.5	
1 : 1 : 2	"	"	12	67.3	
1 : 1 : 3	"	"	"	69.1	
1 : 1 : 1	Piperidine	"	6	43.6	
1 : 1 : 6	Pyridine + traces of piperidine (Robin son's method)	117°	2.5 and then boiling	68.7	
1 : 1 : 10	Pyridine (Vorsatz)	Room	3 weeks	17	
1 : 1 :	" "	"	3 months.	17	
1 : 1	Ether, sufficient	"	3 weeks	0	

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## CONDENSATION OF ALDEHYDES WITH MALONIC ACID. PART XIX CONDENSATION OF CINNAMALDEHYDE

BY BRAHMA SWARUP BANSAL AND KANTILAL C. PANDYA

The condensation of cinnamaldehyde with malonic acid and 1/6 (0.15 mol.) of pyridine give within one hour's heating on a water-bath about 96% yield of cinnamylidene-malonic acid, which is higher than what has been so far recorded. Longer heating gives a mixture of the above dibasic acid with cinnamylidene-acetic acid; prolonged heating gives the mono acid alone, but in less yield. Heating without a base or any condensing agent, a mixture of the two acids is obtained in all the experiments tried.

Hitherto the aldehydes taken up in this series were aromatic aldehydes. Cinnamaldehyde may be looked upon as an aliphatic aldehyde in the sense that the aldehyde group is no longer on the nucleus as in the previous cases, but is on a side-chain, fairly away from the ring. The double bond in the side-chain helps, however, to contact the aldehyde group with the double bond system of the ring in a longer conjugated double bond system. This aldehyde therefore presents certain peculiarities in the aldehyde-malonic acid condensation, and gives yields that are comparable with those obtained from aromatic aldehydes, like benzaldehyde. There is no doubt that the reaction is quite fast, unlike what has been observed with aliphatic aldehydes. Literature on the condensation of purely acyclic aldehydes, as well as the experience obtained in this laboratory on their condensation with malonic acid, suggest that their condensation with malonic acid is not only not very quick, as has been found in the case of the aromatic aldehydes, but that the yields are generally poor and that very often the product contains mixtures of two or more acids (like  $\alpha$ - $\beta$  and  $\beta$ - $\gamma$  unsaturated acids), particularly when secondary amines like piperidine are used (Harding and Weizmann, *J. Chem. Soc.*, 1910, 97, 299). The succeeding paper on the condensation of malonic acid with hydrocinnamaldehyde, where this conjugation of the double bonds is non-existent and the aldehyde group is not connected with the ring in that system, will make this point clear. Cinnamaldehyde thus presents certain interesting contrasts with both aromatic and aliphatic aldehydes.

Though much work has been published on the condensation of cinnamaldehyde (Perkin, *J. Chem. Soc.*, 1877, 1, 403; Stuart, *ibid.*, 1886, 49, 365; Libermann, *Ber.*, 1895, 28, 1439; Knoevenagel, *Ber.*, 1898, 31, 2617; Döbner, *Ber.*, 1902, 35, 2137; Hinrichsen and Triepel, *Annalen*, 1904, 336, 197; Riedel *ibid.*, 1908, 361, 99; Döbner and Staudinger, *Ber.*, 1903, 36, 4322; Riiber, *Ber.*, 1904, 37, 2274) there is no observation recorded (except one from this Laboratory) of condensation in the presence of a trace of pyridine and none either on the condensation carried out in the absence of any condensing agent.

By heating cinnamaldehyde with malonic acid with pyridine-piperidine mixture under reflux for 16 hours, Dutt reported a 60% yield of the cinnamylidene-acetic acid (*J. Indian Chem. Soc.*, 1925, 1, 297). He also noted that on heating for two hours only

"the main product is cinnamylidene-malonic acid, yield nearly 70%" (*ibid.*, p, 335). Boxer and Linstead condensed the two in the presence of triethanolamine, which is not found in this laboratory to be as efficient as pyridine, and found only 10% yield of the cinnamalmalonic acid (*J. Chem. Soc.*, 1931, 740). Dalal and Dutt have condensed the two in the presence of quinoline at 80-85° for 5 hours and obtained about 76% yield of the dibasic acid (*J. Indian Chem. Soc.*, 1932, 9, 309).

Kurien and Pandya, using 0.15 mol. of pyridine for one mol. each of the aldehyde and of malonic acid and heating for only one hour on the water-bath obtained (1931) 90% yield of the cinnamylidene-malonic acid. The dibasic acid was changed to the monobasic (yield 50%) on continuing the heating for 18 hours (*J. Indian Chem. Soc.*, 1934, 11, 825)\*. This suggests some other simultaneous or subsequent reaction taking place, in addition to simple decarboxylation.

The last experiment has now been repeated; it is found that under the usual conditions of the condensation and employing 0.15 mol. of pyridine, the product is a mixture of the di- and the mono-acids. But on restricting the heating to only 1 hour on a water-bath, the maximum yield of 96% of pure dibasic acid is obtained. This is quite comparable with the maximum yield obtained from benzaldehyde-malonic acid (Pandya and Miss Pandya, *Proc. Ind. Acad. Sci.*, 1941, 13A, 116). With a trace of pyridine even 12 hours' heating on a water-bath, continued to give a mixture of the two acids, though the proportion of the mono-acid to that of the dibasic acid, went on increasing as the heating time was increased. In the absence of pyridine also a mixture of the two acids, varying in the same way, was obtained, and none of the two acids came out alone under any condition of heating when no condensing agent was used. Cinnamylidene-malonic acid is a bright yellow crystalline solid, while the monocinnamylidene-acetic acid is white.

## EXPERIMENTAL

### *Condensation in the Presence of Pyridine*

(i) Cinnamaldehyde (1.32 g.), malonic acid (1.04 g.) and 0.13 c. c. of pyridine (1:1:0.15 mol.) were heated together on a water-bath for 6 hours. The reaction started immediately and the mixture changed into a homogeneous liquid in 5 minutes. There was no effervescence, but in another 15 minutes a yellow solid began to separate, and after about  $\frac{1}{2}$  hour's heating the whole reaction mixture became solid. After 3 hours' heating, the yellow solid began to liquify with effervescence, leaving a clear, brown liquid. After full 6 hours' heating, the flask was allowed to cool and left overnight. A yellow-brown solid was found next morning which could all be dissolved in sodium carbonate solution. It was extracted with ether, which gave about 0.2 g. of unused cinnamaldehyde. On acidification of the aqueous solution, a yellow-brown solid was obtained, which was washed with water and dried, yield 1.65 g., m.p. 146-195°, showing that it was a mixture of the two acids. Hot benzene effected a separation into the dibasic cinnamylidene-malonic acid, which was very little soluble, and the monobasic cinnamylidene-acetic acid which dissolved easily.

\*The statement printed in the paper that pyridine was 3 c.c. is a printing mistake; it should have been 0.3 c.c. K. C. P.

The former was recrystallised from alcohol and then from chloroform, m.p.  $206^{\circ}$  (cf. Stuart, *loc. cit.*, m.p.  $208^{\circ}$ ). The mono-acid was recrystallised from hot benzene, then from acetic acid with a drop or so of water; the pure crystals melted at  $165-66^{\circ}$  (cf. Perkin,  $165-86^{\circ}$ , Stuart,  $165^{\circ}$ , *loc. cit.*) The mixture seemed to contain about 56% of the dibasic acid and 44% of the monobasic, the total yield being about 82% of the theoretical (or a little more, if the unused aldehyde is deducted from the aldehyde taken).

(ii) A second experiment was set up in the same way, but the heating was stopped after 3 hours in order to avoid the decarboxylation and to obtain the pure dibasic acid. The product, however, was already semi-solid, and after the removal of 0.1 g. of unused cinnamaldehyde, gave again a mixture of the two acids, but now in the proportion of 80:20, the total yield being about 88%.

(iii) *Preparation of pure Cinnamylidene-malonic Acid.*—The experiment was again repeated, but the heating was stopped after  $\frac{1}{2}$  hour, when the reaction mixture had completely solidified after fusion. Unused cinnamaldehyde was recovered (0.2 g.), and the pure dibasic acid was obtained, m.p.  $206-208^{\circ}$ . After recrystallisation (alcohol) bright yellow needles melted at  $207-208^{\circ}$ , yield 1.75 g. or 94%.

(iv) The experiment was again repeated, but the heating was allowed to go on for 1 hour; this gave the maximum yield of the pure dibasic acid, 96% of theory.

(v) *Preparation of Cinnamylidene-acetic Acid.*—The experiment was repeated with the object of converting all the product into the mono-acid. With 9 hours' heating and with 0.2 g. of the aldehyde recovered unchanged, the product was a mixture containing 24% of the dibasic and 76% of the monobasic acid, total yield being 79%.

(vi) With 12 hours' heating, however, the decarboxylation was complete; the recrystallised mono-acid melted at  $166-67^{\circ}$ , the yield was only 55%, or subtracting the unchanged aldehyde recovered, 61%. As no amount of dibasic acid was recovered and yet the yield had diminished, it is presumed that some of the acid must have undergone another change, possibly dimerisation.

(vii) Cinnamylidene-malonic acid (0.43 g.) was heated in a small flask at  $210-215^{\circ}$  for about  $\frac{1}{2}$  hour. Effervescence continued from the melted mass for about 15 minutes. After cooling and dissolving it in sodium carbonate solution, and after filtering off a little resinous mass, it was acidified, when a white solid, m.p.  $160^{\circ}$ , was obtained. After recrystallisation, the melting-point rose to  $165-66^{\circ}$ , and the acid was identical with cinnamylidene-acetic acid.

(viii) The same amount of the dibasic acid was heated with quinoline (0.26 g.) at  $200^{\circ}$  for 15 minutes. After the usual process of the purification a colorless solid (about 0.25 g.) came out, melting (after recrystallisation from dilute alcohol) at  $137-38^{\circ}$  (Libermann's *allo-cinnamylidene-acetic acid* melts at  $138^{\circ}$ , *loc. cit.*).

#### *Condensation in the Absence of any Condensing Agent*

(i) The same amounts of cinnamaldehyde and malonic acid were heated alone on a water-bath for 9 hours. Within 5 minutes the whole had liquified, effervescence started after about 15 minutes. A yellowish black solid was first formed but it soon disappeared. The next day a black-yellow mass had been formed, which with the

usual treatment, gave a bright yellow solid melting between  $138^{\circ}$  and  $188^{\circ}$  (1.6 g). This was found to contain 40% of the dibasic and 60% of the monobasic acid.

(ii) The heating was stopped after one hour but the product was still a mixture of 85% dibasic and 15% monobasic acid.

(iii) In this experiment, the heating was continued till complete decarboxylation took place, which was ascertained by periodically examining a portion. The heating was for 2 hours on a water-bath and 6 hours at  $110-115^{\circ}$ , the product however, contained 30% of the dibasic acid.

Other experiments, one with heating at  $113-120^{\circ}$  for 10 hours and second with heating at  $120-130^{\circ}$  for 14 hours, failed to completely decarboxylate the product in the absence of pyridine. And yet the decarboxylation seemed to start within one hour on a water-bath.

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CONDENSATION OF ALDEHYDES WITH MALONIC ACID. PART XX.  
CONDENSATION OF 3-NITRO-2-HYDROXYBENZALDEHYDE

BY KANTILAL C. PANDYA, OMENDRA SWARUP SAXENA AND JESSEL DAVID TINKU

3-Nitro-2-hydroxybenzaldehyde (3-nitrosalicylaldehyde) is condensed with malonic acid under different conditions. As in the case of the 5-nitro-2-hydroxybenzaldehyde (Part XVIII) there appears to be no condensation in the absence of any condensing agent or in the presence of glacial acetic acid. In the presence of pyridine, piperidine or a mixture of the two, 3-nitro-2-hydroxybenzylidene (i. e. 3-nitrosalicylidene)-malonic acid is obtained in varying amounts, the highest yield so far obtained being 53%.

This condensation is very much in line with that of 5-nitrosalicylaldehyde under identical conditions. The three peculiarities noted in the earlier paper are found in this condensation also, viz., there is no condensation in the presence of glacial acetic acid or in the absence of any condensing agent, the aldehyde being almost entirely recovered unchanged; in the presence of the bases 3-nitrosalicylidene-malonic acid is obtained, analogous to the 5-nitro product; and the dibasic acid has not been converted, so far, into the corresponding mono-acid by decarboxylation on heating.

The identity of 3-nitrosalicylidene-malonic acid is established by the analytical data; it appears that a nitro or a bromo group adds to the ease of formation and the stability of salicylidene-malonic acid.

The highest yield is 53%, very much below the highest yield obtained of the 5-nitrosalicylidene-malonic acid (part XVIII, *loc. cit.*).

EXPERIMENTAL

The 3-nitrosalicylaldehyde was obtained together with the 5-nitrosalicylaldehyde as described in Part XVIII (Pandya, Saxena and Tinku, *this issue*, p. 443).

Miller and Kinkelin (*Ber.*, 1887, 20, 1931) have condensed 3-nitrosalicylaldehyde by Perkin's method, and obtained 8-nitrocoumarin thereby. On repeating the experiment, however, nothing was obtained. So also Stuart's method (*J. Chem. Soc.*, 1883, 53, 142) i.e. heating on the water-bath 3-nitrosalicylaldehyde with malonic acid in the presence of glacial acetic acid, gave no product, nor was any product isolated when the aldehyde and malonic acid were heated alone together for 12 hours, once on a water-bath and a second time at a higher temperature rising up to 130°.

*With Pyridine.*—Heating the aldehyde and malonic acid with traces of pyridine (0.2 mol.) produced different yields of a certain acid, according to the conditions of heating. Thus 6 hours' heating, either on the water-bath or at 100-105°, produced practically the same yield, viz. 21.1% and 22.2% respectively. (Some aldehyde was recovered unchanged: if this were subtracted, the yield would be greater.) The product was identical, m. p. 182°. The same product was obtained by the other method described below.

With an alteration in the heating, the yield increased. Thus heating at 100-105° or at 98° for 10 hours (in different experiments) gave very nearly the same yield, about 48-49%.

With 1 mol. of pyridine (i.e., 1:1:1 mol.), and heating on a water-bath for 12 hours, the product obtained was 49.3%.

With excess of pyridine (2 mols. and 3 mols.) and heating (water-bath) for 12 hours, the yield was only slightly higher, viz. 52.2%.

*With Piperidine.*—With a molecule of piperidine, and heating on a water-bath for 12 hours, the yield was 41.6%.

*With pyridine-piperidine mixture* (Robinson's method, *J. Chem. Soc.*, 1925, 1977). the yield was about 53%.

Vorsatz's method (*J. prakt. Chem.*, 1936, 145, 265) of room temperature condensation with excess of pyridine, gave in 3 weeks, 21.7% yield.

Kept alone in ether solution, without any condensing agent, for three weeks at room-temperature, it failed to give any product.

The acid product was yellow in colour, melting with effervescence at 182°. It was readily soluble in ether, acetone, alcohol and glacial acetic acid; slightly soluble in benzene, ethyl acetate and cold water; almost insoluble in ether and chloroform; also somewhat soluble in hot water.

The acid gave a deep red colour with concentrated sulphuric acid. It also gave a deep red colour with alcoholic ferric chloride solution; it decolorised Baeyer's reagent, and the solid acid or its solution in glacial acetic acid decolorised bromine readily in the cold. [Found: N, 5.48, 5.68; M. W. (Rast), 258.1; M. W. (Ag. salt), 257.4; équiv. (by titration), 118.4.  $C_{10}H_7O_7N$  (3-nitrosalicylidene-malonic acid) requires N, 5.53%; M. W., 253.3; equiv., 126.5].

Production of colour in the titration, as well as in the camphor in Rast's method, was responsible for greater deviations from the theoretical than is usual.

Experiments to obtain the corresponding monobasic acid by heating the dibasic acid gave an acid melting at about at 151° (O. S. S.); this has still to be investigated.

# STUDIES IN SESQUITERPENES. PART I. SYNTHESIS OF THE TRIMETHYL ESTER OF $C_8H_{15}(CO_2H)_3$ -ACID OBTAINED FROM DIHYDROZINGIBERENE

BY SAILENDRA MOHON MUKHERJEE

Condensation of diethyl  $\alpha$ -methyl- $\alpha$ -(bromoacetyl)-glutarate with malonic ester, followed by hydrolysis and esterification, furnishes (V) which on treatment with zinc and bromoacetic ester gives the lactone (VI). On reduction of the above lactone, followed by esterification, (X), the trimethyl ester of  $C_8H_{15}(CO_2H)_3$  acid, is obtained.

By the oxidative degradation of dihydrozingiberene, which was, in its turn, derived from zingiberene by reduction with sodium and alcohol, Ruzicka and Van Veen (*Annalen*, 1929, 468, 143) obtained a tricarboxylic acid which has been ascribed the constitution (IX). The present investigation deals with the synthesis of the trimethyl ester of the above acid.

A glance at the proposed structure (IX) of this acid reveals that it is a  $\beta$ -substituted adipic acid system. Its synthesis has been accomplished following the usual method for the building of such systems, namely Reformatsky's reaction between ethyl bromoacetate and the corresponding keto-ester, followed by reduction. Ethyl  $\alpha$ -acetylglutarate (I), the starting material for the preparation of the keto-ester (V), is obtained in satisfactory yield in the usual way by the condensation of ethyl  $\beta$ -chloropropionate with ethyl sodio-acetoacetate in benzene. Methylation of ethyl  $\alpha$ -acetylglutarate with sodium (pulverised) and methyl iodide proceeds smoothly to give ethyl  $\alpha$ -methyl- $\alpha$ -acetylglutarate (II). The  $\omega$ -bromo derivative (III) is obtained by the bromination of (II), following the conditions laid down by Conrad and Kreichgauer (*Ber.*, 1897, 30, 856) for the bromination of ethyl dimethylacetoacetate, that is, by the simple addition of bromine in the cold to ethyl  $\alpha$ -methyl- $\alpha$ -acetylglutarate (II), when  $\gamma$ -bromo- $\alpha$ -methyl- $\alpha$ -(ethyl  $\beta$ -propionate)-acetoacetate (III) is obtained as a yellowish oil, which decomposes on distillation presumably with the formation of a keto- $\gamma$ -lactone through the elimination of ethyl bromide from the molecule (*cf.* Conrad and Kreichgauer, *loc. cit.*). The bromo derivative reacts readily and smoothly with ethyl sodiomalonate in benzene to give diethyl  $\alpha\delta$ -dicarbethoxy- $\gamma$ -keto- $\delta$ -methylsuberate (IV) in excellent yield (*cf.* Conrad and Kreichgauer, *loc. cit.*). Few attempts seem to have been reported in the literature to condense the  $\gamma$ -bromo derivatives of ethyl-disubstituted acetoacetate with sodiomalonic ester, although by this means many compounds could be synthetically prepared, the formation of which by other means would have been long and tedious.

The tetracarboxylic ester (IV) is hydrolysed smoothly with concentrated hydrochloric acid. The keto-acid, thus obtained as a thick liquid, is esterified with alcohol and sulphuric acid to give ethyl  $\gamma$ -keto- $\delta$ -methylsuberate (V). This keto-diester is then subjected to Reformatsky's reaction with zinc and ethyl bromoacetate, when a lactone (VI) is obtained. Although it is immaterial for our purpose whether this lactone is a  $\gamma$ - or a  $\delta$ -lactone, the former is preferred since the substance is insoluble in 5% alkali.

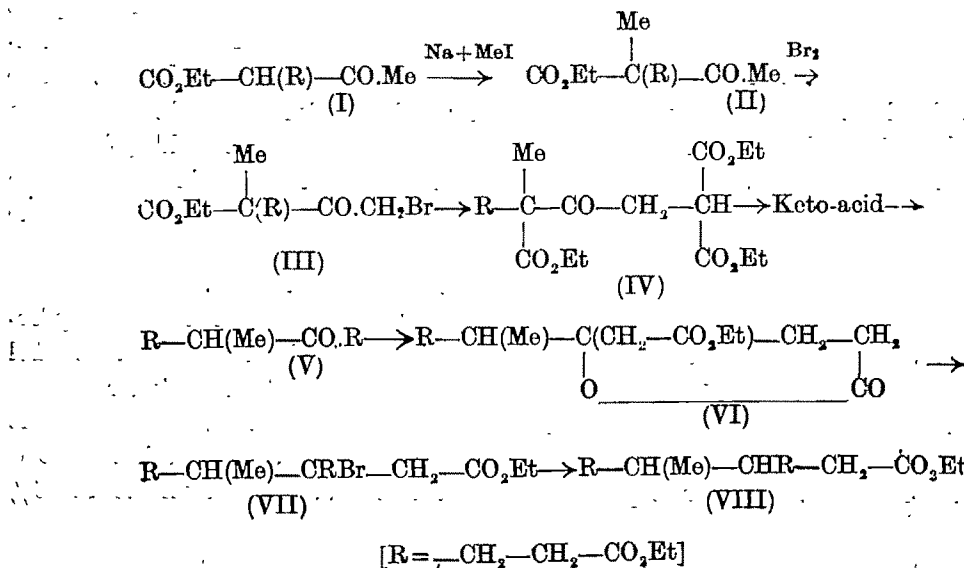


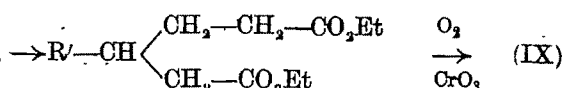
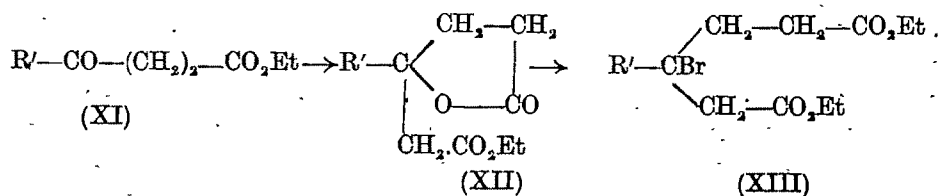
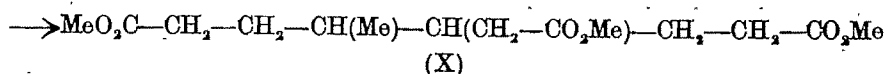
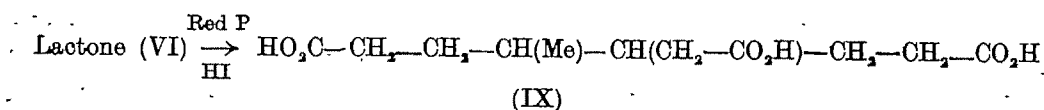
The lactone ring is opened up with phosphorus pentabromide, followed by the treatment of the bromo-acid-bromide with ethyl alcohol. The crude bromo-ester (VII) on being reduced with zinc dust and acetic acid gives the triethyl ester of the tricarboxylic acid (IX). The above lactone is also reduced by red phosphorus and hydriodic acid. The crude acid, thus obtained, could not be solidified, and on esterification with methyl alcohol and sulphuric acid gives the trimethyl ester (X) of the acid (IX). The boiling point of the trimethyl ester agrees well with that of the ester obtained by Ruzicka and Van Veen (*loc. cit.*) by the oxidative degradation of dihydrozingerone. An attempt has been made to obtain the acid in a crystalline form by hydrolysing the above ester but without success.

It will not be out of place to mention another attempt towards the synthesis of the tricarboxylic acid (IX) by a somewhat different route. Ethyl  $\beta$ -(*sec*-isooctyl)-adipate (XIV) was obtained by subjecting ethyl  $\delta$ -isohexylhomolaevulate (XI) to Reformatsky's reaction with zinc and ethyl bromoacetate, followed by reduction of the resulting lactone by opening up the lactone ring with phosphorus pentabromide and alcohol, and subsequent treatment with zinc dust and acetic acid.

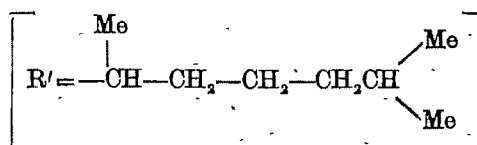
The preparation of ethyl  $\delta$ -isohexylhomolaevulate (XI) has been described in a separate communication (*this issue*). It will be evident that if the isopropyl group at the end of the chain in (XIV) be eliminated through oxidation according to the well known method of Windaus (*Z. physiol. Chem.*, 1921, 117, 146; 1923, 126, 277), the tricarboxylic acid (IX) will be obtained. Similar oxidations have been reported in the literature where an isopropyl group is attacked through oxidation with chromic acid or potassium permanganate (Lawrence, *J. Chem. Soc.*, 1899, 75, 529; Linstead and Rydon, *ibid.*, 1933, 585; Rydon, *ibid.*, 1936, 594).

The present scheme of work may be represented thus:





(XIV)



## E X P E R I M E N T A L

*Diethyl α-Methyl-α-(bromoacetyl)-glutarate* (III).—Diethyl α-acetylglutarate (I, 50 g.) (obtained by condensation of ethyl β-chloropropionate with ethyl sodioacetoacetate) was slowly added to sodium dust (5 g.), suspended in 250 c. c. of dry benzene and left overnight. To the sodio-salt, thus formed, 42 g. (1.5 mol.) of methyl iodide were added and the whole refluxed for 10 hours on the water-bath. Water was added to the cooled reaction mixture and the separated benzene layer was washed and dried. After the removal of the solvent 40 g. of diethyl α-acetyl-α-methylglutarate (II), b. p. 136-38°/6.5 mm. were obtained (the product does not respond to colour reaction with alcoholic ferric chloride).

To the above ester (II, 50 g.), cooled in ice-water, was added dropwise bromine (11 c.c., slight excess of 1 mol.). At first there was observed a lag in the absorption of bromine but once it started, bromine was taken up instantaneously. During the later part of the addition hydrobromic acid was evolved. After the addition of bromine was complete, the reaction mixture was allowed to stand for half-an-hour in the ice-bath and then hydrobromic acid was driven off in the water pump. To assure complete removal of hydrobromic acid the flask was subjected to a higher vacuum (6 mm.) for 1 hour, when a rather thick amber-coloured liquid was obtained.

*Diethyl  $\alpha\delta$ -Dicarbethoxy- $\gamma$ -keto- $\delta$ -methylsuberate* (IV).—Sodium dust (6 g.) under dry benzene (150 c. c.) was cooled in ice-water and diethyl malonate (50 g.) added slowly. The reaction mixture was kept overnight and to this the above crude bromo-ester (III) was added in the cold with shaking and the whole refluxed for 16 hours. The benzene layer, separated after the addition of water to the cooled reaction mixture, was washed with water and dried over calcium chloride. After removal of the solvent the residue was distilled in vacuum, when 72 g. of a thick liquid boiling at  $235\text{--}36^\circ/5$  mm. were obtained. A slight decomposition was observed during distillation. (Found: C, 56.53 ; H, 7.08.  $\text{C}_{18}\text{H}_{30}\text{O}_6$  requires C, 56.7 ; H, 7.46 per cent).

*Diethyl  $\gamma$ -Keto- $\delta$ -methylsuberate* (V).—The above tetracarboxylic ester (IV, 72 g.) was refluxed with 400 c. c. of concentrated hydrochloric acid for 36 hours after which the cooled solution was extracted thrice with ether. The combined ether extract was dried ( $\text{Na}_2\text{SO}_4$ ) and the solvent removed. The residue was dried in vacuum and refluxed with a mixture of 150 c. c. of dry alcohol and 15 c. c. of sulphuric acid ( $d$  1.84) for 20 hours. After dilution with cold water the solution was extracted with ether, the ethereal layer washed with sodium bicarbonate solution, water and dried ( $\text{CaCl}_2$ ). The residue left after the removal of the solvent was distilled in *vacuo* and a colourless, mobile liquid was obtained, b. p.  $160\text{--}61^\circ/7$  mm., yield 25 g. (Found: C, 60.2 ; H, 8.47.  $\text{C}_{13}\text{H}_{22}\text{O}_5$  requires C, 60.46 ; H, 8.52 per cent).

*Diethyl Ester of the Lactone of  $\gamma$ -Hydroxy- $\gamma$ -(acetic acid)- $\delta$ -methylsuberic Acid* (VI).—The keto-diester (V, 25 g.), dissolved in 50 c. c. of benzene was subjected to Reformatsky's reaction with ethyl bromoacetate (8 c. c.) and zinc wool (15 g.) (activated before use by washing it with dilute hydrochloric acid, water and acetone, and dried in vacuum). A few crystals of iodine were added and heated on the water-bath. Within 5 to 6 minutes the colour of iodine disappeared and the solution became turbid and within 15 minutes vigorous reaction took place. After the initial vigour of the reaction had subsided the heating was continued for 1 hour and a fresh addition of 8 c. c. of ethyl bromoacetate, 15 g. of zinc wool (activated) and a few crystals of iodine was made and refluxing continued for 2 hours more. The reaction mixture was shaken from time to time in order to free the surface of zinc from the adhering mass of zinc complex formed in the reaction. It was then cooled and decomposed with acetic acid and methanol, and after considerable dilution with water the benzene layer was taken up and washed with dilute ammonia several times until the ammoniacal layer was almost colourless. Finally the benzene layer was washed with water and dried ( $\text{CaCl}_2$ ). The residue, after the removal of benzene, was distilled in vacuum when 16 g. of the lactone (VI) was obtained, b. p.  $186^\circ/6$  mm. (Found: C, 59.7 ; H, 7.8.  $\text{C}_{13}\text{H}_{24}\text{O}_6$  requires C, 60.0 ; H, 8.0 per cent).

*Diethyl  $\gamma$ -(Ethyl acetate)- $\delta$ -methylsuberate* (VIII).—The lactonic ester (VI, 16 g.) was treated in the cold with  $\text{PBr}_5$  (30 g.) and allowed to stand overnight, when practically the whole of the  $\text{PBr}_5$  went into solution. The thick red solution was poured into 50 c. c. of well cooled absolute alcohol when a vigorous reaction took place. The solution was afterwards refluxed on the water-bath for half-an-hour, cooled and diluted with cold water, and the heavy layer extracted with ether. The ethereal layer was washed with sodium bicarbonate solution and water, and dried ( $\text{CaCl}_2$ ). After the evaporation of

the solvent the residue was dried in *vacuo* and dissolved in 250 c.c. of glacial acetic acid. To this solution was added with shaking zinc dust (40 g.) in small portions during 2 hours and then the reaction mixture was refluxed on a sand-bath for 24 hours. The acetic acid solution was separated from the zinc and cooled, and the major portion of the acetic acid was neutralised with caustic soda solution. The layer, which separated, was extracted with ether, the ethereal layer washed with sodium carbonate solution, water and dried. The residue left after the evaporation of the ether came over at 187-88°/6 mm. (Found: C, 61.4; H, 8.86.  $C_{17}H_{30}O_6$  requires C, 61.8; H, 9.1 per cent).

*Dimethyl  $\gamma$ -(Methyl acetate)- $\delta$ -methylsuberate (X).*—The lactonic diester (VI, 2 g.) was refluxed with an excess of red phosphorus and hydriodic acid (*d* 1.7) for a prolonged period (48 hours). The reaction mixture was diluted, filtered and the filter paper well washed with ether which was added to the filtrate. The ethereal layer was separated and the aqueous layer extracted once more with ether. The combined ether extract was washed with water and dried over sodium sulphate. On removal of the solvent an uncrystallisable resinous mass was left as a residue. The crude product after being dried in *vacuo* was esterified by refluxing with dry methyl alcohol (25 c. c.) and sulphuric acid (4 c. c., *d* 1.84) for 24 hours. After working up in the usual manner, the trimethyl ester (X) was obtained, b.p. 182°/6 mm. (Lit. b. p. 145-150°/0.3 mm.). (Found: C, 57.94; H, 8.16.  $C_{14}H_{24}O_6$  requires C, 58.33; H, 8.33 per cent).

*$\gamma$ -sec.-isoOctyl  $\gamma$ -(Ethyl acetate)- $\gamma$ -butyrolactone (XII).*—Ethyl  $\delta$ -isohexylhomolaevalate (XI, 10 g.) in dry benzene (30 c. c.) was subjected to Reformatsky's reaction with activated zinc wool (5 g.), 3.5 c. c. of ethyl bromoacetate and a crystal or two of iodine according to the procedure described above. Fresh addition of 5 g. of zinc wool and 3.5 c. c. of ethyl bromoacetate and a dry crystal of iodine was made after an hour and refluxing continued for 2 hours more. After cooling, the complex was decomposed with acetic acid and methanol and after dilution with water, extracted with ether. The ether-benzene solution was washed several times with dilute ammonia until the alkaline solution ceased to be coloured, and then with water and dried ( $CaCl_2$ ). After evaporation of ether and benzene from the solution, the residue came over in vacuum at 168°/4 mm., yield 4.5 g. (Found: C, 67.2; H, 9.8.  $C_{16}H_{28}O_4$  requires C, 67.6; H, 9.85 per cent):

*Diethyl  $\beta$ -sec.-isoOctyladipate (XIII).*—The above lactonic ester (4 g.) was treated with  $PBr_5$  (7 g.) according to the procedure described before and the resulting bromo-acid-bromide was treated with 25 c. c. of cooled alcohol and the solution refluxed for 15 minutes. After dilution in the cold with water, a heavy layer settled at the bottom. The mixture was extracted with ether and the ethereal layer washed with  $NaHCO_3$  solution and water. After drying with  $CaCl_2$  the solvent was removed and the residue dried in vacuum.

The crude bromo-ester, thus obtained, was dissolved in 50 c. c. of acetic acid and to this 8 g. of zinc dust added in portions during half-an-hour and the whole refluxed on a sand-bath for 16 hours. After neutralisation of almost 2/3 of the acetic acid with caustic soda solution, the extraction was effected with ether, the ethereal layer washed with sodium carbonate solution and water, and dried. The residue left after the evaporation of the solvent was distilled when a halogen-free liquid came over at

159-60°/4 mm. (Found : C, 68.3 ; H, 9.87.  $C_{14}H_{14}O_4$  requires C, 68.78 ; H, 10.8 per cent).

The author's grateful thanks are due to Prof. P. C. Mitter for his valuable advice and encouragement during the course of these investigations. Thanks are also due to Mr. N. Ghosh for micro-analysis of some of the compounds.

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## THE VARIATION OF RELATIVE VISCOSITY WITH TEMPERATURE

BY A. C. CHATTERJI AND RAM GOPAL

A study of the temperature dependence of relative viscosity  $\eta_s/\eta_0$  of concentrated and supersaturated aqueous solutions of electrolytes has been made. The results show that, provided viscosity remains sufficiently low,  $\delta/\delta_t(\eta_s/\eta_0)$  is positive even in highly concentrated solutions of some electrolytes e. g. KCl, KBr, KI and  $\text{KNO}_3$  etc. Further, the  $\delta/\delta_t(\eta_s/\eta_0)$  is comparatively much high in the solutions of substances which have low hydrating power as compared to those which easily form hydrates with water molecules. These observations have been explained with the help of Rabinowitsch's hydrate hypothesis and the depolymerisation concept of Applebey.

The study of the variation of relative viscosity of solutions with temperature is important because it throws considerable light on the structure of both the solvent and solution. According to Hatschek ("Viscosity of Liquids", 1928), relative viscosity of aqueous solutions of electrolytes, referred to water at the same temperature, rises with temperature. This change is in opposite direction to that of non-electrolytes. For electrolytes the statement of Hatschek is, in general, supported by the observations of Rankine and Taylor (*Trans. Roy. Soc. Edin.*, 1906, 45, 397) and those of Chadwell and Asnes (*J. Amer. Chem. Soc.*, 1930, 52, 3507).

Contrary to the observations of Hatschek and his supporters, Glass and Madgin (*J. Chem. Soc.*, 1934, 1124) noticed that in solutions of  $\text{Na}_2\text{SO}_4$ , down to 0.78N,  $\eta_s/\eta_0$  decreases with temperature. Similar behaviour is shown by solutions of  $\text{Na}_2\text{CO}_3$ ,  $\text{CaCl}_2$ , and salts of Li, Mg and Ca at all known concentrations. In general, negative temperature coefficient of  $\eta_s/\eta_0$  is found in concentrated solutions and in salts which dissolve to form hydrated ions.

In connection with a thesis (unpublished) on supersaturated solutions, the viscosity of a large number of aqueous solutions of substances of varying nature has been studied. This offered an opportunity to study the question of variation of  $\eta_s/\eta_0$  with temperature in a little more detail and also to examine the state of affairs in supersaturated solutions.

### EXPERIMENTAL

The measurements of viscosity were carried out by the method of Scarpa (*Gazzetta*, 1910, 40, 271), as modified by Forrow (*J. Chem. Soc.*, 1912, 101, 347) and Taimini (*J. Phys. Chem.*, 1928, 32, 604). In this method, the measurement of the density of the solution is not required, the viscosity being given by the equation

$$\eta = K \frac{t_1 t_2}{t_1 + t_2}$$

where  $t_1$  is the time required for sucking the liquid under a known pressure and  $t_2$ , that of the fall under the atmospheric pressure and  $K$  is a constant which depends upon the dimensions of the viscometer. The density occurs only in the term used for kinetic energy correction (which is very small as compared to the first term) and hence a slight

inaccuracy in the density measurements does not affect the results to any appreciable extent. The corrected viscosity  $\eta_c$  is given by the equation

$$\eta_c = K \frac{t_1 t_2}{t_1 + t_2} - N \rho \frac{t_1^2 + t_2^2}{t_1 t_2 (t_1 + t_2)}.$$

Hence this method is specially suitable to supersaturated solutions where the measurement of density below the saturation temperature is sometimes impossible and is always very difficult. Although the method is not very reliable for dilute solutions (cf. Chatterji and Vaish, *J. Indian Chem. Soc.*, 1935, 12, 6), it is quite suitable for solutions investigated here.

From the experimental results obtained by the above method the values of  $\eta_s/\eta_0$  have been calculated for two different concentrations at various temperatures. Some data of Taimini (*J. Phys. Chem.*, 1939, 33, 56) have also been utilised to calculate the relative viscosity. Table I gives the results thus obtained.

TABLE I

Substance.	Conc.*	$\eta_s/\eta_0$ at						
		30°.	35°.	40°.	45°.	50°.	55°.	60°.
1. KCl	37.4	1.117	1.142	1.169	1.195	1.227	1.248	—
	41.4	—	—	1.214	1.248	1.266	1.284	1.313
2. KBr	70.5	1.080	1.112	1.150	1.180	1.210	1.242	—
	82.5	—	—	—	1.253	1.302	1.317	1.347
3. KI	153.0	1.212	1.252	1.290	1.338	1.379	1.422	—
	168.4	—	—	1.397	1.448	1.505	1.530	1.565
4. KNO <sub>3</sub>	54.0	1.1185	1.215	1.249	1.274	1.302	1.311	—
	72.8	—	—	1.410	1.445	1.474	1.510	1.545
5. KClO <sub>3</sub>	12.3	—	1.007	1.024	1.030	1.036	1.041	—
	19.7	—	—	—	—	1.068	1.075	1.090
6. KBrO <sub>3</sub>	0.88	0.998	1.000	1.024	1.030	1.036	1.037	—
	1.47	—	—	—	1.069	1.073	1.076	1.085
7. KIO <sub>3</sub>	10.99	1.079	1.081	1.084	1.085	1.093	1.096	—
	16.43	—	—	—	1.149	1.149	1.149	1.158
8. K <sub>2</sub> SO <sub>4</sub>	12.6	1.168	1.175	1.184	1.196	—	1.209	—
	17.1	—	—	1.278	1.296	1.299	1.301	1.304
9. K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	30.4	1.038	1.054	1.064	1.074	1.086	1.092	1.109
	31.7	—	—	—	—	1.231	1.236	1.247
10. K <sub>4</sub> FeCy <sub>6</sub>	30.4	1.437	1.475	1.496	1.515	1.510 (?)	1.578	—
	42.8	—	1.757	1.785	1.805	1.834	1.846	1.878
11. NaNO <sub>3</sub>	92.5	3.003	3.009	3.026	3.016	2.988	2.940	—
	113.8	—	—	3.771	3.766	3.767 (?)	3.715	3.699
12. NaClO <sub>3</sub>	110.5	3.613	3.516	3.477	3.435	3.422	3.366	—
	139.6	—	—	4.528	4.457	4.438	4.353	—
13. Na Acetate	54.6	6.431	5.940	5.623	5.299	5.111	4.827	—
	83.8	13.73	—	10.90	—	9.80	9.175	—

\* Concentration is expressed in grams of solute in 100 g. water.

Substance.	Conc.	30°.	35°.	40°.	45°.	50°.	55°.	60°.
14. $\text{NH}_4\text{Cl}$	41.88 48.00	1.087 —	1.126 —	1.169 1.223	1.198 1.253	1.216 1.285	1.253 1.311	— 1.312
15. $(\text{NH}_4)_2\text{SO}_4$	76.0 86.2	2.925 —	— —	2.931 3.303	2.968 3.333	2.988 3.366	3.115 3.386	— 3.433
16. $(\text{NH}_4)_2\text{C}_2\text{O}_4$	7.1 13.1	1.106 —	1.119 —	1.126 —	— 1.234	1.134 1.242	— —	— 1.257
17. $\text{K}_2\text{C}_2\text{O}_4$	46.2 56.7	1.702 —	1.731 —	1.761 2.038(?)	— 2.01	1.807 2.025	— 2.039	— 2.069
18. $\text{H}_2\text{C}_2\text{O}_4$	21.6 56.7	1.276 —	1.287 —	1.306 —	1.286 1.680	1.277 1.681	1.211 1.658	— 1.651
19. $\text{NH}_4\text{NO}_3$	250.0 365.0	2.557 —	2.589 —	2.679 4.319	2.756 4.311(?)	2.850 4.379	2.887 4.426	— 4.503
20. $\text{Ba}(\text{NO}_3)_2$	11.75 17.16	1.104 —	— —	1.111 —	1.115 1.190	1.120 1.195	— 1.199	— 1.203
21. $\text{BaCl}_2$	38.1 43.8	1.540 —	— —	1.585 1.706	— —	1.622 1.754	1.628 1.759	— 1.770
22. $\text{KCNS}$	242.0 320.0	3.876 —	3.889 —	3.950 5.808	4.010 5.855	4.036 5.910	4.102 5.937	— 6.008
23. $\text{CuSO}_4$	50.89 70.33	2.903 —	2.837 —	2.786 3.923	2.742 3.828	2.704 3.741	— 3.638	— 3.558
24. $\text{MgSO}_4$	145.6 215.1	11.27 —	10.71 21.42	10.36 19.83	9.865 18.60	9.486 17.71	9.113 —	— 19.07
25. Tartaric acid	156.0 193.6	16.17 —	14.51 26.16	13.56 23.59	— 21.05	11.75 19.29	11.05 —	— 19.01
26. $(\text{OH})_2 \begin{cases} \text{COOH} \\ \text{COOH} \end{cases}$	10.8 24.4	1.204 —	1.211 —	1.203 —	1.201 1.524	1.203 1.504	1.202 1.484	— 1.476
27. $\text{Pb}(\text{NO}_3)_2$	60.0 —	1.581 —	1.568 —	1.582 1.867	1.692 1.853	1.597 1.857	— 1.861	— 1.874
28. $\text{CS} \begin{cases} \text{NH}_2 \\ \text{NH}_2 \end{cases}$	19.94 44.6	1.084 —	1.087 —	1.088 —	1.100 1.236	1.105 1.297	1.113 1.301	— 1.305
29. $\text{HgCl}_2$	9.60 11.34	— —	1.039 —	1.045 —	— 1.058	1.047 1.067	1.048 1.058	1.049 1.062

From the data of Taimini.

 $\eta_1/\eta_0$  at

	Conc.	20°.	30°.	35°.	40°.	45°.	50°.
30. Sucrose in water	233 350	— —	296.2 —	230.7 2245	182.7 1656	92.53 1141	12.36 828.0
31. Urea in water	120 151	— —	2.178 2.533	2.174 2.534	2.189 2.533	— 2.525	2.254 2.528
32. $\text{Na}_2\text{S}_2\text{O}_3$ in water	73 119	6.761 35.05	5.875 19.00	5.526 —	5.327 15.68	5.166 14.67	— —
33. Acetamide in water	100 200	— —	2.875 4.376	2.735 4.144	2.635 3.958	2.550 3.799	— —
34. Citric acid in water	161 207	24.45 56.46	19.75 41.50	— —	16.64 32.10	15.17 27.50	— —



Table I leads to the following general conclusions :

(i). In all cases, where the viscosity is sufficiently small, irrespective of whether the concentration is high or low, e. g. in solution of KCl, KBr, KI and  $\text{KNO}_3$ , etc., the relative viscosity increases with temperature i. e.  $\delta/\delta_t(\eta_s/\eta_0)$  is positive.

(ii). Where  $\delta/\delta_t(\eta_s/\eta_0)$  is negative, the solutions are invariably highly viscous in comparison to those belonging to the first category. The reverse is not, however, strictly true e. g. in solutions of  $\text{NH}_4\text{NO}_3$ ,  $(\text{NH}_4)_2\text{SO}_4$  and KCNS etc., where viscosity is high yet  $\delta/\delta_t(\eta_s/\eta_0)$  is positive.

(iii). In the case of organic solutes, data are not sufficient for any generalisation to be arrived at, although  $\delta/\delta_t(\eta_s/\eta_0)$  appears to be negative at a comparatively low concentration, a fact observed by previous workers and also pointed out by Hatschek; there are enough data (e. g. urea, thiourea etc.) to show that  $\delta/\delta_t(\eta_s/\eta_0)$  is positive even in organic solutes under certain circumstances and hence Hatschek's general statement cannot be accepted *in toto*.

#### DISCUSSION

The expression  $\delta/\delta_t(\eta_s/\eta_0)$  for any particular system will be positive if the variations in  $\eta_s$  are smaller as compared to those in  $\eta_0$  i. e.,  $\eta_0$  should change more rapidly as the temperature is raised. It is then obvious that the pure solvent should have more associated or complex molecules at lower temperatures and these should break into simpler molecules as the temperature is raised. The solvent (water here) is known to consist of mostly  $(\text{H}_2\text{O})_3$  and  $(\text{H}_2\text{O})_2$  molecules at ordinary temperatures and these break up into simpler entities as the temperature is raised. Reverse will be the case if the temperature is lowered. In an aqueous solution of any substance (electrolyte or non-electrolyte), the water molecules cluster round the ions or molecules of the solute depending mainly upon the electrical density (unless some other forces are at play) in their neighbourhood, and thus an increase in viscosity of solutions results. When temperature is raised, these clusters or solvates break up and abnormally lower the viscosity of the solutions over and above the effect due to rise in temperature alone i. e. due to increase in the kinetic energy. In dilute solutions this effect may be very small as compared to that when water complexes are alone involved (this will be clear from the 'depolymerisation' effect discussed below). Under these circumstances then,  $\delta/\delta_t(\eta_s/\eta_0)$  will be positive in general i. e. in dilute solutions  $\eta_s/\eta_0$  will rise with temperature in almost all cases, a fact already pointed out in the beginning of the paper.

If the concentration of the solute is further raised, the amount of water involved in the hydration will be much increased and a stage will be reached when the effect of temperature on solvates will outweigh the effect of heat on water complexes themselves. At this stage  $\delta/\delta_t(\eta_s/\eta_0)$  changes sign and will become negative. This is the 'hydrate concept' of Rabinowitsch (*J. Amer. Chem. Soc.*, 1922, **44**, 954) who considers that, in solution, highly hydrated salts show negative temperature coefficient of relative viscosity owing to progressive decomposition of hydrates as the temperature rises.

From the above discussion it is clear that the phenomenon of negative temperature coefficient of relative viscosity will be more common in solutions of high viscosity and in substances which form solvates with the solvent.

When an electrolyte dissolves in water, it causes a depolymerisation of water molecular complexes, as has been first suggested by Sutherland (*Phil. Mag.*, 1900, *v*, 50, 481) and then later elaborated by Applebey (*J. Chem. Soc.*, 1910, 97, 2000). This effect lowers the viscosity of the system, and if the balancing effect of solvation is not sufficient (i. e. in cases where hydration effect is very small, e. g. solutions of KCl, KBr and KI etc.), it may, in fact, reduce the viscosity of the solutions even lower than that of water itself. This is the cause of what is known as 'negative viscosity' discovered by Wagner\* (*Z. physikal. Chem.*, 1891, 5, 31). From this conception an explanation at once emerges as to why in the case of certain salts like KCl, KBr, KI and  $\text{KNO}_3$  etc., no negative temperature coefficient of relative viscosity is observed even when the concentration is very high. They are very little hydrated and this factor does not contribute much to increase the viscosity of the system. Besides, more and more complexes are depolymerised as the concentration of the electrolyte is increased and at sufficient concentration of electrolyte, there may not be many complexes left to be broken up by the rise in temperature. Consequently, relative rise in the value of  $\eta_s/\eta_0$  with temperature should be greater in these cases as compared to substances which form hydrates; but due to low concentration, the factor  $\delta/\delta_s(\eta_s/\eta_0)$  is still positive. A rough idea may be obtained of this from the fact that increase in the value of  $\eta_s/\eta_0$  per  $5^\circ$  rise in temperature in the case of KCl, KBr, KI,  $\text{NH}_4\text{Cl}$ ,  $\text{KNO}_3$  varies from 3% to 6%, where as in  $\text{KIO}_3$ ,  $\text{Ba}(\text{NO}_3)_2$ ,  $\text{BaCl}_2$ ,  $\text{K}_2\text{C}_2\text{O}_4$ , and  $\text{K}_2\text{SO}_4$ , etc., it is in most cases even less than 1%, but in no case more than 2%. Similarly, in non-electrolytes e. g. urea, thiourea etc., which do not depolymerise water molecular complexes to any great extent, due to a very low, if at all, electric charges on them, the value of  $\eta_s/\eta_0$  should increase, if at all, very slowly with rise in temperature. In these cases increase is always less than 1% and generally lies between 0.1% and 0.5%.

The following general conclusions, based on the conception of molecular association and depolymerisation, may be found useful in the future development of the subject.

(i) If the solvent consists of simple molecules and the solute, which dissolves in it, does not in any way interact with the solvent molecules, the value of  $\delta/\delta_s(\eta_s/\eta_0)$  should be approximately zero.

(ii) If the solvent is associated and the associated complexes break as the temperature rises and the solute does not affect the solvent molecules in any way, then the expression  $\delta/\delta_s(\eta_s/\eta_0)$  will always be positive.

(iii) If the solute forms solvates or associates in any way with the solvent molecules forming easily breakable molecular complexes, and the solvent consists of

\*Poiseuille (*Ann. chim. phys.*, 1847, *iii* 21, 76), 'found that some salts increased the viscosity and others decreased it'. This statement appears in a paper by Jones and Dole (*J. Amer. Chem. Soc.*, 1929, 51, 2950). From this it appears that the phenomenon was discovered by Poiseuille but probably he did not realise its significance.

simple molecules, then the temperature coefficient of relative viscosity  $\delta/\delta_t(\eta_s/\eta_0)$  will always be negative.

(iv). If the molecules of the solvent are associated among themselves and also the solute dissolved forms solvates, then  $\delta/\delta_t(\eta_s/\eta_0)$  will be positive or negative depending upon which one of the two factors predominates. If the former predominates,  $\delta/\delta_t(\eta_s/\eta_0)$  will be positive and if the latter, it will be negative.

(v). If the solvent molecules are associated and the depolymerisation of the solvent molecular complexes occurs when the solute is dissolved in it, and the solute does not show much solvate effect, then  $\delta/\delta_t(\eta_s/\eta_0)$  will be positive and high. But if the solvate effect is present, then  $\delta/\delta_t(\eta_s/\eta_0)$  will be positive and low at lower concentration and will change over to negative when the solvate effect predominates.

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# AN EMPIRICAL EQUATION RELATING EXTINCTION COEFFICIENT WITH FREQUENCY IN AN ABSORPTION BAND

By B. C. KAB

An empirical equation relating extinction coefficient with frequency in an absorption band has been developed which can be used in all forms of absorption curves and from this the equation of circular dichroism and rotatory dispersion in the region of absorption have been deduced.

It is well known that there is a quantitative relation between absorption, circular dichroism and circular double refraction (optical activity) in optically active absorbing media. Kuhn and Braun (*Z. physikal. Chem.*, 1930, **8 B**, 281) obtained such a relation which is

$$\alpha = \frac{57.3}{2\sqrt{\pi}} \frac{(\epsilon_l - \epsilon_r)_{\max}}{\log_{10} e} \cdot \frac{\nu}{\nu_0} \left[ e^{-\left(\frac{\nu_0 - \nu}{\theta}\right)^2} \int_0^{\frac{\nu_0 - \nu}{\theta}} e^{x^2} dx - \frac{\theta}{2(\nu_0 + \nu)} \right]$$

where  $\alpha$  is the rotatory contribution of an optically active absorption band, expressed in degrees per cm. column of the solution at frequency  $\nu$ ;  $(\epsilon_l - \epsilon_r)_{\max}$  is the maximum value of circular dichroism of that band at frequency  $\nu_0$  and the parameter  $\theta$  is related to the half-width of the experimental curve of circular dichroism of the band by the relation:  $\nu$  (half-width) =  $1.6651\theta$ . This equation was modified by Lowry and Hudson (*Phil. Trans.*, 1933, **A**, 232, 117). All these rotatory dispersion equations are based on the absorption equations which represent the absorption curves responsible for optical activity. It is therefore important to determine first of all the mathematical form of absorption curves which can subsequently be used to deduce equations for curves of circular dichroism and rotatory dispersion. The existing equations of absorption by Ketteler-Helmholtz (Lowry, "Optical Rotatory Power," Cambridge, 1935, p 395); by Kuhn (*Z. physikal. Chem.*, 1929, **4B**, 14; *Trans. Faraday Soc.*, 1930, **26**, 293), by Kuhn and Braun (*loc. cit.*) by Lowry and Hudson (*loc. cit.*) and by Bielecki and Henri (*Physikal. Z.*, 1913, **14**, 516) cannot be used in all forms of absorption curves and cannot also represent the experimental data satisfactorily. Thus, the equation of Ketteler and Helmholtz

$$\epsilon = \frac{a\lambda^2}{(\lambda^2 - \lambda_m^2)^2 + g^2\lambda^4}$$

represents an absorption curve which is unsymmetrical both with respect to frequencies and to wave-lengths. When plotted on a scale of frequencies, it is steeper on the low-frequency side and, when plotted on a scale of wave-lengths, it is steeper on the short wave-length side. The equation of Kuhn, namely

$$\epsilon = \epsilon_{\max} \cdot \frac{\nu^2 \nu_0^2}{(\nu_0^2 - \nu^2)^2 + \nu^2 \nu_0^2} \simeq \epsilon_{\max} \frac{\nu^2}{4(\nu_0 - \nu)^2 + \nu^2}$$

and that of Kuhn and Braun, namely,  $\epsilon = \epsilon_{\max} \cdot e^{-\left(\frac{\nu_0 - \nu}{\theta}\right)^2}$  represent absorption curves

which are symmetrical on a scale of frequencies. The equation of Lowry and Hudson, namely

$$\epsilon = \epsilon_{\max} \cdot e^{-\left(\frac{\lambda - \lambda_0}{\theta}\right)^2}$$

represents curve which is symmetrical when plotted on a scale of wave-lengths, but steeper on the low-frequency side when plotted on a scale of frequencies. Lastly, the equation

$$\epsilon = a\nu e^{-\beta(\nu - \nu_0)^2}$$

of Bielecki and Henri, represents curve which is steeper on the low-frequency side when plotted on a scale of frequencies. In the present communication a new empirical equation has been developed which can be used in all forms of absorption curves, either symmetrical or unsymmetrical on a scale of frequencies or wave-lengths.

For the purpose of analysis of an absorption curve, plotted on a scale of frequencies, we divide the curve into two components, one on the low-frequency side of  $\epsilon_{\max}$ , and the other on the high-frequency side of  $\epsilon_{\max}$ , where  $\epsilon_{\max}$  is the maximum value of extinction coefficient in the experimental curve corresponding to the frequency  $\nu_0$ . The extinction coefficient  $\epsilon$ , corresponding to any frequency  $\nu$  on the low-frequency side, can be represented by the equation

$$\epsilon = \epsilon_{\max} \cdot e^{-\left(\frac{\nu_0 - \nu}{\theta_1}\right)^2}, \text{ where } \theta_1 = \frac{\nu_0 - \nu_1}{0.8326},$$

$\nu_1$  being the frequency of the point at the experimental curve on the low-frequency side at which  $\epsilon$  is half  $\epsilon_{\max}$ . Similarly the extinction coefficient  $\epsilon$ , corresponding to any frequency  $\nu$  on the high-frequency side, can be represented by the equation

$$\epsilon = \epsilon_{\max} \cdot e^{-\left(\frac{\nu - \nu_0}{\theta_2}\right)^2} \text{ where } \theta_2 = \frac{\nu_2 - \nu_0}{0.8326},$$

$\nu_2$  being the frequency of the point on the high-frequency side at which  $\epsilon$  is half  $\epsilon_{\max}$ . The factor 0.8326 ensures that the theoretical curve calculated by the above equations coincides with the experimental curve at the two points  $\nu_1$  and  $\nu_2$  as well as  $\nu_0$ . If the curve is symmetrical, we have  $(\nu_0 - \nu_1) = (\nu_2 - \nu_0)$  so that

$$\theta_1 = \theta_2 = \frac{\nu_0 - \nu_1}{0.8326} = \frac{2(\nu_0 - \nu_1)}{1.6652} = \frac{\nu'}{1.6652} = \theta$$

where  $\nu'$  is called the half-width of the band.

The absorption equation for a symmetrical curve therefore becomes

$$\epsilon = \epsilon_{\max} \cdot e^{-\left(\frac{\nu_0 - \nu}{\theta}\right)^2} \text{ where } \theta = \frac{\nu'}{1.6652}$$

This equation is the same as the equation of Kuhn and Braun which gives a theoretical absorption curve symmetrical on a scale of frequencies. These new equations there-

fore can be used to represent any curve, whether symmetrical or unsymmetrical. For symmetrical curve, the value of  $\theta_1$  is equal to  $\theta_2$ , while for unsymmetrical curve, they are different. Similar equations hold good when the curve is plotted on a scale of wave-lengths, namely, for longer wave-length side of  $\epsilon_{\max}$

$$\epsilon = \epsilon_{\max} \cdot e^{-\left(\frac{\lambda - \lambda_0}{\theta_1}\right)^2}$$

where  $\theta_1 = \frac{\lambda_1 - \lambda_0}{0.8326}$  and for the shorter wave-length side of  $\epsilon_{\max}$ ,  $\epsilon = \epsilon_{\max} \cdot e^{-\left(\frac{\lambda_0 - \lambda}{\theta_2}\right)^2}$

where  $\theta_2 = \frac{\lambda_0 - \lambda_2}{0.8326}$ ,  $\lambda_1$  and  $\lambda_2$  being the wave-lengths at which  $\epsilon$  is half  $\epsilon_{\max}$

The applicability of these new absorption equations has been tested in the case of unsymmetrical absorption curves of acetone in water and alcohol, and the absorption curve of acetaldehyde in water studied by Bielecki and Henri (*loc. cit.*).

Bielecki and Henri determined the molecular extinction coefficient of pure acetone, solutions of acetone in water and alcohol and of solutions of acetic acid and acetaldehyde in water for different wave-lengths in the ultraviolet region. By applying the Ketteler and Helmholtz equation, they found a discrepancy between the observed extinction coefficient and the theoretical values. They therefore proposed the exponential formula,

$$\epsilon = a\nu e^{-\beta(\nu - \nu_0)^2}$$

which represented the experimental data better than the Ketteler-Helmholtz equation. It is found that a still better agreement is obtained by applying the new equations given above. The observed values and the theoretical values calculated according to all these three equations are tabulated in Tables I, II and III.

TABLE I

*Absorption of acetone in water.*

Equation of Ketteler and Helmholtz :  $a = 1.43 \times 10^6$  ;  $g^2 = 7.8 \times 10^4$  ;  $\lambda_m = 2655\text{\AA}$ .

Equation of Bielecki & Henri :  $a = 1.57 \times 10^{-2}$  ;  $\beta = 1.18 \times 10^{-4}$  ;  $\nu_0 = 1133$ .

Kar's equation :  $\epsilon_{\max} = 17.8$  ;  $\nu_0 \times 10^{-14} = 11.33$  ;  $\nu_1 \times 10^{-14} = 10.56$  ;

$\theta_1 \times 10^{-14} = 0.9249$  ;  $\nu_2 \times 10^{-14} = 12.3$  ;  $\theta_2 \times 10^{-14} = 1.165$ .

$\lambda$	$\epsilon$ obs.	$\epsilon$ calc. (K & H)	$\epsilon$ calc. (B & H)	$\epsilon$ calc. (Kar)	$\lambda$	$\epsilon$ obs.	$\epsilon$ calc. (K & H)	$\epsilon$ calc. (B & H)	$\epsilon$ calc. (Kar)
2144	0.54	1.03	0.0053	0.10	2705	16.2	18.3	16.3	16.64
2265	2.16	1.80*	0.28*	1.21	2744	14.0	13.16*	14.21*	14.77
2307	3.2	2.24	0.77	2.28	2815	10.8	8.4	9.87	10.37
2352	4.6	2.90*	1.79*	3.95	2852	8.1	6.46	7.64	8.26
2398	7.0	3.8	3.82	6.38	2892	5.5	5.02*	5.49*	6.06
2444	9.4	5.26*	6.80*	9.20	2928	4.04	4.10	4.08	4.44
2468	10.8	6.25*	8.64*	10.85	2960	2.7	3.46*	2.99*	3.40
2539	14.0	10.7	14.0	15.02	2981	2.16	3.13	2.70	2.78
2575	16.2	13.70*	16.21*	16.51	3001	1.62	2.84	1.96	2.23
2648	17.8	18.3	17.8	17.8	3040	1.08	2.40	1.03	1.46

\*These values have been calculated by us.

TABLE II

*Absorption of acetone in alcohol.*Equation of Beilecki & Henri :  $a=1.42 \times 10^{-2}$  ;  $\beta=1.525 \times 10^{-4}$  ;  $\nu_0=1109$ .Kar's equation :  $\epsilon_{\max}=15.8$  ;  $\nu_0 \times 10^{-14}=11.09$  ;  $\nu_1 \times 10^{-14}=10.28$  ; $\theta_1 \times 10^{-14}=0.9729$  ;  $\nu_2 \times 10^{-14}=11.94$  ;  $\theta_2 \times 10^{-14}=1.021$ .

$\lambda$ .	$\epsilon$ obs.	$\epsilon$ calc. (K & H)	$\epsilon$ calc. (B & H)	$\epsilon$ calc. (Kar)	$\lambda$ .	$\epsilon$ obs.	$\epsilon$ calc. (K & H)	$\epsilon$ calc. (K & H)	$\epsilon$ calc. (Kar)
2288	1.4	2.42	0.037	0.315	2708	15.8	15.8	15.8	15.8
2331	2.16	2.93	0.154*	0.79	2770	14.0	14.9	13.98	14.63
2382	3.5	3.72	0.58*	1.83	2845	10.8	11.57	9.67	11.48
2405	4.2	4.17	1.11	2.55	2981	5.5	6.25	2.94*	5.27
2488	7.0	6.41	4.09*	6.41	3047	3.2	4.71	1.35	3.07
2581	10.80	10.5	12.14	12.07	3120	1.4	3.57	0.48	1.58
2648	14.0	14.0	14.84	14.95	3280	0.054	2.16	0.042	0.29

\*Values calculated by us.

TABLE III

*Absorption of acetaldehyde in water.*
 $\epsilon_{\max}=6.35$  ;  $\nu_0 \times 10^{-14}=10.85$  ;  $\nu_1 \times 10^{-14}=10.04$  ;  $\theta_1 \times 10^{-14}=0.9729$  ;  $\nu_2 \times 10^{-14}=11.79$  ;  $\theta_2 \times 10^{-14}=1.129$ .

$\lambda$ .	$\epsilon$ obs.	$\epsilon$ calc. (B & H)	$\epsilon$ calc. (Kar)	$\lambda$ .	$\epsilon$ obs.	$\epsilon$ calc. (B & H)	$\epsilon$ calc. (Kar)
2393	1.30	0.22	0.69	2892	5.2	4.57	4.98
2460	1.8	0.78	1.52	2926	4.4	3.85	4.34
2480	2.16	1.04	1.86	2981	3.6	2.73	3.34
2525	2.75	1.9	2.76	3001	2.8	2.41	2.95
2550	3.61	2.85	3.27	3047	2.3	1.68	2.18
2620	4.3	4.3	4.79	3079	1.4	1.32	1.74
2630	4.6	4.54	5.01	3100	1.3	1.05	1.49
2684	5.4	5.72	5.88	3140	0.70	0.70	1.08
				3200	0.27	0.37	0.64

Similar to the new absorption equation, the equation of circular dichroism will be

$$(\epsilon_l - \epsilon_r) = (\epsilon_l - \epsilon_r)_{\max} \cdot e^{-\left(\frac{\nu_0 - \nu}{\theta_1}\right)^2} \quad \text{for frequencies less than } \nu_0, \text{ and}$$

$$(\epsilon_l - \epsilon_r) = (\epsilon_l - \epsilon_r)_{\max} \cdot e^{-\left(\frac{\nu - \nu_0}{\theta_2}\right)^2} \quad \text{for frequencies greater than } \nu_0$$

where  $\nu_0$  is the frequency corresponding to maximum circular dichroism  $(\epsilon_l - \epsilon_r)_{\max}$ and  $\theta_1 = \frac{\nu_0 - \nu_1}{0.8326}$  and  $\theta_2 = \frac{\nu_2 - \nu_0}{0.8326}$  ;  $\nu_1$  and  $\nu_2$  are the frequencies at which  $(\epsilon_l - \epsilon_r)$  is halfthe maximum value in the experimental curve of circular dichroism. If  $(\epsilon_l - \epsilon_r)$  is

$$\text{plotted against } \lambda, \text{ the equations become } (\epsilon_l - \epsilon_r) = (\epsilon_l - \epsilon_r)_{\max} \cdot e^{-\left(\frac{\lambda - \lambda_0}{\theta_1}\right)^2} \quad \text{for wave-lengths}$$

greater than  $\lambda_0$ , and  $(\epsilon_i - \epsilon_r) = (\epsilon_i - \epsilon_r)_{\max} \cdot e^{-\left(\frac{\lambda_0 - \lambda}{\theta_2}\right)^2}$  for wave-lengths less than  $\lambda_0$ ,  $\theta_1$  being equal to  $\frac{\lambda_1 - \lambda_0}{0.8326}$  and  $\theta_2 = \frac{\lambda_0 - \lambda_2}{0.8326}$ .

The partial rotation contributed by an optically active absorption band in the region of absorption and outside it can therefore be obtained by the equations:

$$\alpha = \frac{57.3}{2\sqrt{\pi}} \cdot \frac{(\epsilon_i - \epsilon_r)_{\max}}{\log_{10} e} \cdot \frac{\nu}{\nu_0} \left[ e^{-\left(\frac{\nu_0 - \nu}{\theta_1}\right)^2} \int_0^{\frac{\nu_0 - \nu}{\theta_1}} e^{x^2} dx - \frac{\theta_1}{2(\nu_0 + \nu)} \right]$$

for frequencies less than  $\nu_0$ , and

$$\alpha = -\frac{57.3}{2\sqrt{\pi}} \cdot \frac{(\epsilon_i - \epsilon_r)_{\max}}{\log_{10} e} \cdot \frac{\nu}{\nu_0} \left[ e^{-\left(\frac{\nu - \nu_0}{\theta_2}\right)^2} \int_0^{\frac{\nu - \nu_0}{\theta_2}} e^{x^2} dx + \frac{\theta_2}{2(\nu_0 + \nu)} \right]$$

for frequencies greater than  $\nu_0$ .

$(\epsilon_i - \epsilon_r)_{\max}$ ,  $\nu_0$ ,  $\theta_1$  and  $\theta_2$  have the same significance and values as in the curve of circular dichroism of the optically active absorption band and  $\alpha$  is the rotatory contribution expressed in degrees per cm. column of the solution.

Expressed in wave-lengths,

$$\alpha = \frac{57.3}{2\sqrt{\pi}} \cdot \frac{(\epsilon_i - \epsilon_r)_{\max}}{\log_{10} e} \cdot \frac{\lambda_0}{\lambda} \left[ e^{-\left(\frac{\lambda - \lambda_0}{\theta_1}\right)^2} \int_0^{\frac{\lambda - \lambda_0}{\theta_1}} e^{x^2} dx + \frac{\theta_1}{2(\lambda + \lambda_0)} \right]$$

for wave-lengths greater than  $\lambda_0$ , and

$$\alpha = -\frac{57.3}{2\sqrt{\pi}} \cdot \frac{(\epsilon_i - \epsilon_r)_{\max}}{\log_{10} e} \cdot \frac{\lambda_0}{\lambda} \left[ e^{-\left(\frac{\lambda_0 - \lambda}{\theta_2}\right)^2} \int_0^{\frac{\lambda_0 - \lambda}{\theta_2}} e^{x^2} dx - \frac{\theta_2}{2(\lambda + \lambda_0)} \right]$$

for wave-lengths less than  $\lambda_0$ .

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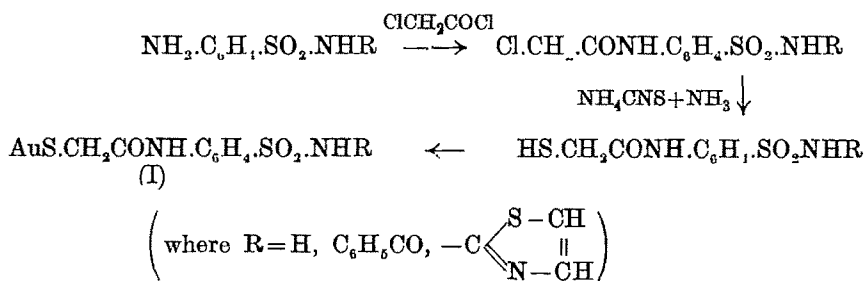
# AUROTHIOACYL COMPOUNDS FROM SULPHA DRUGS

BY U. P. BASU AND J. SIKDAR

Certain aurothioacyl compounds from sulphonamides have been described.

Recently certain drugs of sulpha group have been found to exert an anti-tubercular activity in *vivo*. The fundamental condition for their effectiveness is attributed to the presence of *p*-aminobenzoic acid in the culture medium in which tubercle bacillus is grown (*cf.* Ekstrand and Sjogren, *Nature*, 1945, 156, 476) indicating thereby that the above bacterium also requires the above acid as an essential metabolite. As gold compounds are often valued in the treatment of pulmonary tuberculosis, asthma, leprosy and chronic arthritis, it is considered to be of interest to prepare certain compounds of gold with well known sulpha drugs and subsequently to study their therapeutic effectiveness in the above diseases. The work that has been so far carried out are described in this paper.

Sulphanilamide, homosulphanilamide, sulphanilylbenzamide and sulphathiazole are useful antibacterial agents. With chloroacetyl chloride they afford the chloroacetyl derivatives, which on treatment with ammonium thiocyanate and subsequent heating with ammonia give the corresponding thiol derivative. The latter reacts with aurous bromide in alcoholic solution to afford the respective gold compound (I) as follows :—



Homosulphanilamide again affords a different type of compound,  $\text{AuS} \cdot \text{CH}_2 \text{CONH} \cdot \text{CH}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{SO}_2 \cdot \text{NH}_2$ . Their pharmacological characteristics are being studied.

## EXPERIMENTAL

### *p*-Aurothioglycolylaminobenzene Sulphonamide

(a). *Chloroacetamidobenzene sulphonamide*.—Sulphanilamide (1 mol.) was dissolved in acetone and 10% caustic soda solution (1 mol.) added to it and the mixture was cooled in ice. Chloroacetyl chloride (1.25 mol.), also dissolved in acetone and cooled in ice, was added to the solution of sulphanilamide in small quantities with shaking. After the addition was over, the solution was acidified with dilute hydrochloric acid. A greenish white precipitate was obtained which was filtered, washed with water and

crystallised from boiling water (charcoal) as fine colourless needles, m. p.  $217^{\circ}$  (Found : N, 11.45 ; Cl, 14.21.  $C_8H_9O_3N_2ClS$  requires N, 11.26 ; Cl, 14.28 per cent).

(b). *p*-Thioglycolylaminobenzene Sulphonamide.—The above compound (1 mol., finely powdered) was suspended in alcohol (95%) and heated to  $60-70^{\circ}$  on a water-bath. Powdered ammonium thiocyanate (1 mol.) was added to it and the mixture was kept at this temperature with stirring for 3 hours. A pasty mass was obtained. It was triturated for one hour with water in a mortar and the separated solid was filtered, washed with water several times and then transferred to a flask and heated with excess of dilute ammonia on a water-bath till almost the whole of it went into solution. The solution was filtered, the filtrate cooled in ice and then acidified with dilute hydrochloric acid till a rose colour developed with methyl orange solution. The precipitate separating was filtered, washed with water and then crystallised from methyl alcohol (charcoal) in white needles, m. p.  $264^{\circ}$  (decomp.). (Found : N, 11.49 ; S, 25.53.  $C_8H_{10}O_3N_2S_2$  requires N, 11.38 ; S, 25.61 per cent).

(c). *p*-Aurothioglycolylaminobenzene Sulphonamide ( $NH_2.SO_2.C_6H_4.NHCOCH_2.SAu$ ).—The thioglyco-sulphonamidobenzanilide was dissolved in alcohol with warming and the solution was added to a solution of aurous bromide in alcohol (95%), prepared by passing sulphur dioxide through an alcoholic solution of potassium auribromide till the solution was colourless. The white precipitate that was formed was allowed to settle in the dark, then filtered, washed several times with water to remove sulphur dioxide, washed three times with alcohol (95%) and then thrice with absolute alcohol and finally thrice with petroleum ether and then dried in a vacuum desiccator in the dark. (Found : Au, 43.83.  $C_8H_9O_3N_2S_2Au$  requires Au, 44.57 per cent).

*Aurothioglycolylhomosulphanilamide* ( $NH_2.SO_2.C_6H_4.CH_2.NHCOCH_2.SAu$ )

Homosulphanilamide (1 mol.) was dissolved in alcohol (95%) and chloroacetic acid (1 mol.) dissolved in alcohol (95%) was added to it in small quantities with stirring, keeping the temperature below  $20^{\circ}$ . After the addition was over, the mixture was kept at  $20^{\circ}$  for 3 hours, when a pasty mass was obtained. It was then heated to  $60^{\circ}-70^{\circ}$  on a water-bath and powdered ammonium thiocyanate (1 mol.) was added to it with stirring. At first a solution was obtained and then after some time a precipitate began to appear. When the precipitation was complete, the mixture was triturated with water and proceeding in the same way as in the previous case, the thiol compound was obtained, m. p.  $193-94^{\circ}$  (Found : N, 10.88 ; S, 24.53.  $C_9H_{12}O_3N_2S_2$  requires N, 10.77 ; S, 24.61 per cent). The gold compound was prepared from the thiol derivative as in the previous case as a white powder. (Found : Au, 42.79.  $C_9H_{11}O_3N_2S_2Au$  requires Au, 43.20 per cent)

*p*-Aminobenzene Sulphon-(aurothioglycol) amide ( $NH_2.C_6H_4.SO_2.NHCOCH_2.SAu$ )

*p*-Acetamidobenzene sulphonamide (1 mol.) was treated with chloroacetyl chloride (1.25 mol.) in acetone solution. The chloroacetyl derivative, thus obtained, was hydrolysed with dilute caustic soda solution in the customary way and on just neutralising with dilute hydrochloric acid, the free base was obtained. It was crystallised from alcohol in needles. (Found : N, 11.38 ; Cl, 14.19.  $C_8H_9O_3N_2ClS$  requires N, 11.26 ; Cl, 14.28 per cent).

The chloro compound was treated with ammonium thiocyanate as usual and the

thioglycolamide was obtained in white crystals darkening above  $300^{\circ}$ . (Found : N, 11.43 ; S, 25.57.  $C_8H_{10}O_4N_2S_2$  requires N, 11.38 ; S, 25.61 per cent).

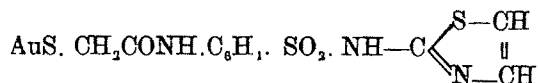
This thio compound on treatment with aurous bromide in the usual manner gave the gold compound as a white powder. (Found: Au, 43.42  $C_8H_8O_3N_2S_2Au$  requires Au, 44.57 per cent)

*p-Aurothioglycolylaminobenzene Sulphonbenzamide* ( $C_6H_5CONH.SO_2.C_6H_4.NHCOCH_2.SAu$ )

Sulphanilylbenzamide was treated with chloroacetyl chloride in the usual way. The chloroacetyl derivative thus obtained was treated with ammonium thiocyanate in the customary way and the thiol compound was obtained. (Found : N, 8.11 ; S, 18.42.  $C_{15}H_{11}O_4N_2S_2$  requires N, 8.00 ; S, 18.3 per cent).

From the thiol compound the gold derivative was obtained in the usual manner as a white powder (Found : Au, 35.48  $C_{15}H_{10}O_4N_2S_2Au$  requires Au, 36.08 per cent)

*Aurothioglyco-sulphathiazole*

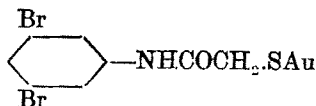


Sulphathiazole was treated with chloroacetyl chloride as before and the chloroacetyl derivative was crystallised from alcohol in needles, m. p.  $237^{\circ}$  (decomp.). (Found : N, 12.71 ; Cl, 10.68.  $C_{11}H_{10}O_4N_3S_2Cl$  requires N, 12.67 ; Cl, 10.70 per cent).

From this chloro compound the thiol derivative was obtained in the usual way. It was crystallised from ethyl acetate in slender needles. (Found : N, 12.89 ; S, 29.03.  $C_{11}H_{11}O_3N_3S_3$  requires N, 12.76 ; S, 29.18 per cent).

Proceeding in the usual manner the gold compound was prepared from the thiol derivative. (Found : Au, 36.79.  $C_{11}H_{10}O_3N_3S_3Au$  requires Au, 37.52 per cent).

*Aurothioglycol-3:5-dibromoanilide*



3:5-Dibromoaniline (m. p.  $56-58^{\circ}$ ) was prepared according to the method of Holleman (*Chem. Zentr.*, 1906, II, 771) from *p*-nitroaniline, and treated with chloroacetic acid as usual. The reaction product was directly reacted with ammonium thiocyanate to get the thioglyco-3:5-dibromoanilide (Found: N, 4.49 ; S, 9.86  $C_8H_7ONSBr_2$  requires N, 4.31 ; S, 9.84 per cent). Its gold compound has not yet been isolated in pure state.

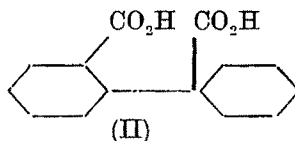
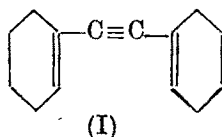
## SYNTHETIC INVESTIGATIONS IN DICYCLOHEXANE DERIVATIVES. PART II

BY PASUPATI SEN-GUPTA AND BIDYUT KAMAL BHATTACHARYYA

Ethyl 1-cyano *cyclohexyl*cyanoacetate on condensation with ethyl  $\delta$ -bromovalerate, followed by hydrolysis and esterification furnishes ethyl  $\alpha$ -(1-carbethoxy-*cyclohexyl*)-pimelate which on Dieckmann condensation, hydrolysis and esterification yields 2-keto-1'-carbethoxydicyclohexane. 1-(1'-Carboxy-*cyclohexyl*)-2-carboxy- $\Delta^1$ -*cyclohexene* is obtained through the cyanohydrin of the above keto-ester.

Marvel *et al.* (*J. Amer. Chem. Soc.*, 1936, 58, 972) claimed to have synthesised  $\Delta^{11}$ -dodecahydro-9-phenanthrone by the cyclisation of the diyne (I) with 85% formic acid. But Levitz, Perlmann and Bogert (*J. Org. Chem.*, 1941, 105) from a study of spiro(*cyclohexane*-1:1'-*indan*) suggested that the ketone possessed a spirane skeleton, which rearranged to phenanthrene derivatives under the conditions of dehydrogenation.

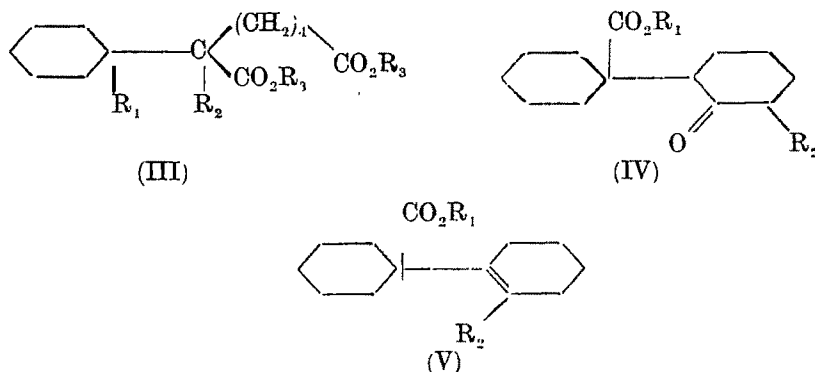
Linstead *et al.* (*J. Chem. Soc.*, 1939, 842; *J. Amer. Chem. Soc.*, 1942, 64, 1996) oxidised the saturated ketone formed by hydrogenation of Marvel's ketone with nitric acid and obtained a dibasic acid to which structure (II) has been proposed.



The synthesis of this dicarboxylic acid (II), has been attempted along the following line.

*cyclohexanone* has been condensed with ethyl cyanoacetate according to Cope's modification of Knoevenagel's reaction (*J. Amer. Chem. Soc.*, 1941, 63, 3452). Hydrocyanic acid adds to the ethyl *cyclohexylidene*-cyanoacetate (Hope and Sheldon, *J. Chem. Soc.*, 1922, 121, 2223) to yield ethyl 1-cyanocyclohexyl-cyanoacetate in an excellent yield. The same dicyano-ester was also prepared by Dickens, Horton and Thorpe (*J. Chem. Soc.*, 1924, 1830) by condensing *cyclohexanone* cyanohydrin with ethyl sodio-cyanoacetate, but the yield in the present method is better. The condensation of  $\delta$ -bromovaleric ester with the above dicyano-ester has been effected in alcoholic solution in presence of sodium ethoxide when ethyl  $\alpha$ -(1-cyanocyclohexyl)- $\alpha$ -cyanopimelate (III,  $R_1=R_2=CN$ ;  $R_3=Et$ ) is formed. The above condensation cannot be effected with potassium dust in xylene solution. The dicyano-ester (III,  $R_1=R_2=CN$ ;  $R_3=Et$ ) has been hydrolysed by refluxing first with 70% sulphuric acid and then with 20% aqueous alkali when  $\alpha$ -(1-carboxycyclohexyl)-pimelic acid (III,  $R_1=CO_2H$ ;  $R_2=R_3=H$ ) is obtained. The ethyl ester of this  $\alpha$ -substituted pimelic acid (III,  $R_1=CO_2Et$ ;  $R_2=H$ ;  $R_3=Et$ ) after ring-closure by Dieckmann's method furnishes a  $\beta$ -keto-ester (IV,  $R_1=Et$ ;

$R_2 = \text{CO}_2\text{Et}$ ) which on hydrolysis with a mixture of acetic acid, concentrated hydrochloric acid and water yields 1'-carboxy-2-keto-dicyclohexane (IV,  $R_1 = R_2 = \text{H}$ ).



The cyanohydrin of the ethyl ester of the keto-acid (IV,  $R_1 = \text{Et}$ ;  $R_2 = \text{H}$ ) has been prepared according to the method of Ultee (*Rec. trav. chim.*, 1909, 28, 1). The yield is very low due to steric hindrance in the molecule. The cyanohydrin on dehydration by the addition of thionyl chloride and pyridine furnishes 1-(1'-carbethoxy)-cyclohexyl-2-cyan- $\Delta^1$ -cyclohexene (V,  $R_1 = \text{Et}$ ;  $R_2 = \text{CN}$ ). Attempts to effect the hydrolysis of this unsaturated nitrile with 80% phosphoric acid, with a mixture of acetic acid, sulphuric acid and water or with 20% aqueous caustic potash in an atmosphere of nitrogen proved futile. On hydrolysis with 70% sulphuric acid, followed by a 25% aqueous caustic potash solution 1-(1'-carboxycyclohexyl)-2-carboxy- $\Delta^1$ -cyclohexene (V,  $R_1 = \text{H}$ ,  $R_2 = \text{CO}_2\text{H}$ ) of m. p.  $157-59^\circ$  is obtained. But due to the very low yield the next step i. e., catalytic hydrogenation to dicyclohexyl-1:2'-dicarboxylic acid could not be effected.

#### EXPERIMENTAL

**Ethyl 1-Cyanocyclohexylcyanoacetate.**—Ethyl cyclohexylidene-cyanoacetate (69 g.) was dissolved in rectified spirit (430 c. c.). Potassium cyanide (46.8 g.) in water (252 c. c.) was added to the ester dropwise. To the cold mixture was added hydrochloric acid (57.3 c. c.) with water (40.3 c. c.) at  $10^\circ$ . Concentrated hydrochloric acid (114.6 c. c.) and powdered ice were added to the reaction mixture when ethyl 1-cyanocyclohexylcyanoacetate was precipitated; it was extracted with ether, dried and distilled, b. p.  $165-168^\circ/4-5$  mm., yield 64 g. A small portion was crystallised from low boiling petroleum ether in fine prism-like crystals, m. p.  $48^\circ$ . (Found : C, 65.08; H, 7.29.  $\text{C}_{12}\text{H}_{16}\text{O}_2\text{N}_2$  requires C, 65.45; H, 7.27 per cent).

**Ethyl  $\alpha$ -(1-Cyanocyclohexyl)- $\alpha$ -cyanopimelate** (III,  $R_1 = R_2 = \text{CN}$ ;  $R_3 = \text{Et}$ ).—Ethyl 1-cyanocyclohexylcyanoacetate (57 g.), dissolved in alcohol (57 c. c.) was added to sodium ethoxide (prepared by dissolving 5.9 g. sodium in 200 c. c. of absolute alcohol), cooled in a freezing mixture and the reaction mixture was kept in the freezing mixture for half an hour. Then ethyl  $\delta$ -bromovalerate (60 g.) was added and refluxed for 24 hours. The condensation product was treated with ice-water, extracted with ether and distilled, b. p.  $220^\circ/3$  mm., yield 53 g. (Found : C, 64.95; H, 8.11.  $\text{C}_{19}\text{H}_{28}\text{O}_4\text{N}_2$  requires C, 65.52; H, 8.05 per cent).

$\alpha$ -(1-Carboxycyclohexyl)-pimelic Acid (III,  $R_1 = \text{CO}_2\text{H}$ ;  $R_2 = R_3 = \text{H}$ ).—The above dicyano-ester (53 g.) was refluxed gently for 4 hours with a mixture of concentrated sulphuric acid (265 c.c.), acetic acid (185.5 c.c.) and water (79.5 c.c.). A considerable portion carbonised. The product was distilled with steam to drive away acetic acid and extracted with ether after dilution with ice-water. The product still contained nitrogen and it was further refluxed for 30 hours with caustic potash (75 g.) in water (210 c.c.). The product was acidified with concentrated sulphuric acid (40 c.c.) in ice-water, extracted with ether and dried. After removing ether the residue solidified in a vacuum desiccator. The crude solid was crystallised from acetic acid, m. p.  $152^\circ$ , yield 26 g.

The hydrolysis of the same dicyano-ester was effected in a better yield with 70% sulphuric acid. The dicyano-ester (30 g.) was refluxed for 12 hours with concentrated sulphuric acid (105 c.c.) and water (90 c.c.). The reaction product was diluted with ice-water, extracted as usual and further refluxed for 30 hours with caustic potash (75 g.) in water (225 c.c.). The product was worked up in the usual way, yield 22 g. (Found: C 58.8; H, 7.8.  $\text{C}_{14}\text{H}_{22}\text{O}_6$  requires C, 58.74; H, 7.69 per cent).

Ethyl  $\alpha$ -(1-Carbethoxycyclohexyl)-pimelate ( $R_1 = \text{CO}_2\text{Et}$ ;  $R_2 = \text{H}$ ;  $R_3 = \text{Et}$ ).—The above tribasic acid (26 g.) was esterified by refluxing on the water-bath for 70 hours with ethyl alcohol (100 c.c.) and concentrated sulphuric acid (d 1.14, 18 c.c.). The product was diluted with ice-water, extracted with ether and distilled, b. p.  $190^\circ/3$  mm., yield 19 g. (Found: C, 64.72; H, 8.92.  $\text{C}_{20}\text{H}_{34}\text{O}_6$  requires C, 64.8; H, 9.19 per cent).

2-Keto 1':3-dicarbethoxy-dicyclohexane (IV,  $R_1 = \text{Et}$ ;  $R_2 = \text{CO}_2\text{Et}$ ).—Ethyl  $\alpha$ -(1-carbethoxycyclohexyl)-pimelate (19 g.) was refluxed in dry benzene (50 c.c.) with sodium dust (2.3 g.) and dry ethyl alcohol (3 c.c.) for 18 hours on a water-bath. The product was treated with sulphuric acid (6 c.c.) in ice. The  $\beta$ -keto-ester was extracted with benzene and distilled, while a portion decomposed, b. p.  $178\text{--}186^\circ/5\text{--}6$  mm., yield 12 g. (Found: C, 68.6; H, 8.6.  $\text{C}_{18}\text{H}_{28}\text{O}_6$  requires C, 66.6; H, 8.64 per cent). The deviation is due to the decomposition of the  $\beta$ -keto-ester during distillation.

2-Keto-1'-carbethoxydicyclohexane (IV,  $R_1 = R_2 = \text{H}$ ).—(a) The above  $\beta$ -keto-ester (12 g.) was refluxed with 20% sulphuric acid (100 c.c.) for 20 hours. The product still contained portions insoluble in alkali. It was further refluxed for 4 hours with caustic potash (10 g.), methanol (50 c.c.) and water (10 c.c.). The reaction mixture was acidified and extracted with ether. On removing ether the crude product containing 2-keto-1'-carboxydicyclohexane was esterified by refluxing for 30 hours on the water-bath with ethyl alcohol (50 c.c.) and concentrated sulphuric acid (d 1.84, 5 c.c.). The product was worked up as usual, from which 2-keto-1'-carbethoxydicyclohexane was distilled, b. p.  $136^\circ/3$  mm., yield, 6.5 g.

(b) A better method was to reflux the above  $\beta$ -keto-ester (20 g.) with acetic acid (125 c.c.), concentrated hydrochloric acid (62.5 c.c.) and water (12.5 c.c.) for 24 hours. The extraction and esterification of the crude acid was the same as described above, b. p.  $165^\circ/8$  mm., yield 9.3 g. (Found: C, 70.74; H, 9.5.  $\text{C}_{18}\text{H}_{28}\text{O}_3$  requires C, 71.42; H, 9.52 per cent).

2-Hydroxy-2-cyano-1'-carbethoxydicyclohexane.—(a). The preparation of the cyano-hydrin was first attempted according to the method of Butenandt, Schmidt and Thome (Ber., 1938, 71, 1487) but without success.

(b) Dry hydrogen cyanide was passed into the above keto-ester (3.8 g) taken in a test tube with a drop of aqueous potassium cyanide solution and cooled below  $-10^{\circ}$ . When in the test-tube there were two layers; it was corked, the contents were thoroughly mixed and left overnight in a refrigerator. After adding one drop of sulphuric acid hydrogen cyanide was driven off from the product, which was then extracted with ether. The cyanohydrin was crystallised from petroleum ether, m. p.  $87-88^{\circ}$ , yield 0.89 g. (Found: C, 69.21; H, 9.18.  $C_{16}H_{26}O_3N$  requires C, 68.8; H, 8.97 per cent).

1-(1'-Carboxycyclohexyl)-2-carboxy- $\Delta^1$ -cyclohexene (V,  $R_1=Et$ ;  $R_2=CN$ ).—The above cyanohydrin (0.6 g.) was dehydrated in pyridine (0.7 c.c.), cooled in ice by the addition of thionyl chloride (0.33 c.c.) drop by drop and refluxing for 2 hours on a water-bath after leaving the reaction mixture overnight. The product was acidified with hydrochloric acid (2 c.c.) in ice, extracted with ether and 1-(1'-carbethoxycyclohexyl)-2-cyano- $\Delta^1$ -cyclohexene was distilled, b.p.  $165^{\circ}/3$  mm., yield 0.45 g.

(a). The unsaturated cyano-ester (1.4 g) was refluxed for 10 hours with phosphoric acid (16 c.c.) in water (4 c.c.). But no hydrolysis could be effected by this method.

(b). The unsaturated cyano-ester (1.4 g.) was refluxed for 10 hours with concentrated sulphuric acid (10 c.c.), acetic acid (7 c.c.) and water (3 c.c.). The product carbonised and no acid could be isolated from it.

(c). The cyano-ester (1.2 g.) was next refluxed for 8 hours with 70% sulphuric acid (12 c.c.). The product still contained nitrogen. The crude product was further refluxed with 25% aqueous caustic potash (20 c.c.) for 24 hours. The product was acidified and extracted as usual. After dissolving the product in acetic acid a few crystals of 1-(1'-carboxycyclohexyl)-2-carboxy- $\Delta^1$ -cyclohexene, of m. p.  $157-59^{\circ}$  were obtained, but the yield was unsatisfactory. (Found: C, 66.58; H, 7.92.  $C_{14}H_{20}O_4$  requires C, 66.66; H, 7.93 per cent).

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# INDIGOID VAT DYES OF THE ISATIN SERIES. PART VI. 3-INDOLE-2'-(7'-CHLORO) THIONAPHTHENE-INDIGOS

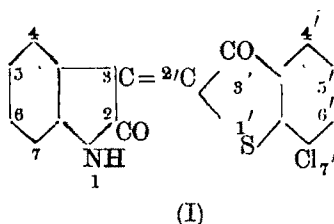
BY SISIR KUMAR GUHA AND JNANENDRA NATH CHATTERJEE

7-Chloro-3-hydroxythionaphthene has been condensed with isatin and a few of its substituted products. The 3-indole-2'-(7'-chloro)thionaphthene-indigos are found to be lighter than their parent substances and the corresponding 5'-chloro compounds. The preparation and the properties of 7:7'-dichlorothioindigo have been studied.

In part V of this series of papers (Guha and Basu-Mallick, *J. Indian Chem. Soc.*, 1946, 23, 214), the effect of a chlorine atom was studied when present in the 5'-position of the thionaphthene ring of 3-indole-2'-thionaphthene-indigo (Thioindigo scarlet-R) and some of its substituted products (Ciba Red G etc.).

The present investigation was undertaken with the idea of studying the effect of a chlorine atom in the 7'-position of the thionaphthene-indigos. The primary aim is to make a complete study of the influence of a chlorine atom when present in all the available positions of the thionaphthene ring of 3-indole-2'-thionaphthene-indigos.

With this object in view, 7-chloro-3-hydroxythionaphthene (Dalglish and Mann, *J. Chem. Soc.*, 1945, 893) has been condensed with isatin and some of its substituted products and another new series of asymmetrical thioindigoid dyes has been obtained having the general constitutional formula (I).



These vat dyes are darkish red, deep red and violet-red crystalline substances, the yield of each of which is quite high, varying between 80 and 90% of the theoretical value. All of them melt above 320°. They are soluble in pyridine and nitrobenzene. The parent substance and its 5-chloro-, and 5-bromo-substituted compounds are sparingly soluble in carbon tetrachloride, whereas the dibromo-, bromonitro-, and dinitro-substituted dyes are insoluble in the same solvent. The last three dyes are also insoluble in alcohol. The dyeing shades of all these products have been uniformly developed on wool from a dilute sulphuric acid bath and on cotton from an alkaline hydrosulphite vat. The colour of the vat, which was obtained at 65°-70°, is yellow in every case except the dinitro compound whose vat is brownish yellow, from which the original colour of all the dyes reappears on atmospheric oxidation.

It has been observed that these dyeing shades are lighter in colour than those developed from the corresponding 5'-chloro compounds (Guha and Basu-Mallick, *loc. cit.*) and their parent substances, pointing to the conclusion that the change in colour is



in the order : 5'-chloro compound > parent compound > 7'-chloro compound. In Table I, the dyeing shades on cotton obtained from the compounds of these three series have been laid down for comparison.

TABLE I

T = Thionaphthene-indigo.

Compounds.	Dyeing shades on cotton.
3-Indole-2'-T	Scarlet-red
3-Indole-2'-(5'-chloro)-T	Deep red
3-Indole-2'-(7'-chloro)-T	Darkish red
3-(5:7-Dibromo) indole-2'-T	Yellowish red
3-(5:7-Dibromo) indole-2'-(5'-chloro)-T	Violet-red
3-(5:7-Dibromo) indole-2'-(7'-chloro)-T	Violet-red (lighter shade)
3-(5:7-Dinitro) indole-2'-T	Dark red
3-(5:7-Dinitro) indole-2'-(5'-chloro)-T	Deep violet-red
3-(5:7-Dinitro) indole-2'-(7'-chloro)-T.	Dirkish violet-red

Dalgliesh and Mann (*loc. cit.*) related 7:7'-dichlorothioindigo but the details of its preparation, its chemical and dyeing properties and melting point were not recorded. This compound was required for studying the change in colour of the isomeric dichlorothioindigos. It is a violet-red needle shaped dye and lighter in shade than its isomeride, 5:5'-dichlorothioindigo.

One of the present authors (Guha, *J. Indian Chem. Soc.*, 1938, 15, 20 ; 1943, 20, 37) prepared a pure specimen of 4-methyl-, and 7-methyl-3-hydroxythionaphthene, m. p. 75-76° and 80-81° respectively. Dalgliesh and Mann (*loc. cit.*) prepared these compounds by different methods and recorded m. p. 65-68° and 73-78° respectively.

#### EXPERIMENTAL

**3-Indole-2'-(7'-chloro)thionaphthene-indigo.**—Isatin (1.029 g.) was dissolved in boiling glacial acetic acid (30 c.c.) and 7-chloro-3-hydroxythionaphthene (1.2915 g.) was added to it. The resulting deep red solution on treatment with strong hydrochloric acid (6 c. c.) separated the dye in thick crystalline mass. More of glacial acetic acid (20 c. c.) was added to the mixture and boiled for 15 minutes, filtered hot, washed with a little acetic acid and hot water. The product (1.7825 g., 81.4%) was crystallised from benzene in fine small thread-like darkish red needles. It is moderately soluble in alcohol, acetic acid and benzene. Strong sulphuric acid dissolves it producing a violet-red solution. It dyes wool in darkish red shade from an acid bath and cotton in the same shade from an alkaline hydrosulphite vat. (Found: C, 60.9 ; H, 2.6.  $C_{16}H_8O_2NClS$  requires C, 61.2 ; H, 2.5 per cent).

3-(5-*Chloro*) indole-2'-(7'-*chloro*) thionaphthene-indigo was prepared in a similar way by boiling a solution of 5-chloro-isatin (0.5445 g.) and 7-chloro-3-hydroxythionaphthene (0.5535 g.) in glacial acetic acid (60 c. c.) and strong hydrochloric acid (5 c. c.) for 20 minutes. The sharp, needle-shaped, crystalline, silky, darkish red dye (0.969 g., 81.3%) was crystallised from nitrobenzene in long needles. It is soluble in aniline, moderately soluble in acetic acid, sparingly soluble in benzene, xylene and alcohol. The solution of this dye in strong sulphuric acid is violet. It dyes wool and cotton in darkish red shade. (Found : C, 54.7 ; H, 2.31.  $C_{16}H_7O_2NCl_2S$  requires C, 55.1 ; H, 2.01 per cent).

3-(5-*Bromo*) indole-2'-(7'-*chloro*) thionaphthene-indigo.—The deep red solution, produced by dissolving 5-bromo-isatin (0.678 g.) and 7-chloro-3-hydroxythionaphthene (0.5535 g.) in boiling glacial acetic acid (65 c. c.) separated, on treatment with strong hydrochloric acid (4-5 c. c.) and boiling for 25 minutes, the darkish red, soft, needle-shaped crystals (1.093 g., 92.8%). It was crystallised from nitrobenzene in long needles. The solubility of this dye and also its dyeing shades on wool and on cotton resemble the preceding compound. (Found : C, 48.4 ; H, 1.92.  $C_{16}H_7O_2NClBrS$  requires C, 48.9 ; H, 1.78 per cent).

3-(5:7-*Dibromo*) indole-2'-(7'-*chloro*) thionaphthene-indigo was obtained in clusters of deep red needles (1.235 g., 87.3%) from a solution of 5:7-dibromo-isatin (0.915 g.) and 7-chloro-3-hydroxythionaphthene (0.5535 g.) in glacial acetic acid (75 c. c.) when treated with strong hydrochloric acid (4 c. c.) and boiled for 25 minutes. It was crystallised from pyridine in small woolly needles. It is sparingly soluble in xylene and more so in benzene and acetic acid. Strong sulphuric acid dissolves it producing a brick-red solution. It imparts a light violet-red shade to wool from an acid bath and violet-red shade to cotton from an alkaline hydrosulphite vat. (Found : C, 40.4 ; H, 1.22.  $C_{16}H_5O_2NClBr_2S$  requires C, 40.7 ; H, 1.27 per cent).

3-(5-*Bromo*-7-*nitro*) indole-2'-(7'-*chloro*) thionaphthene-indigo.—5-Bromo-7-nitro-isatin (0.813 g.) and 7-chloro-3-hydroxythionaphthene (0.5535 g.) were dissolved in boiling glacial acetic acid (90 c. c.) ; strong hydrochloric acid (3 c. c.) was added to the mixture and boiled for 15 minutes. The violet-red product (1.128 g., 86.1%) was crystallised from nitrobenzene in flaky crystals. It is moderately soluble in xylene, sparingly soluble in acetic acid. The solution of the substance in strong sulphuric acid is violet. It dyes wool in light violet shade from an acid bath and cotton in darkish violet-red shade from hydrosulphite vat. (Found C, 43.5 ; H, 1.05.  $C_{16}H_5O_4N_2ClBrS$  requires C, 43.88 ; H, 1.37 per cent).

3-(5:7-*Dinitro*) indole-2'-(7'-*chloro*) thionaphthene-indigo was prepared by boiling a glacial acetic acid (85 c. c.) solution of 5:7-dinitro-isatin (0.711 g.) and 7-chloro-3-hydroxythionaphthene (0.5535 g.) and strong hydrochloric acid (4 c. c.) for 25 minutes. The violet-red dye (1.04 g., 86.6%) was crystallised from nitrobenzene in aggregate of small needles. It is sparingly soluble in xylene, acetic acid and more so in benzene. Strong sulphuric acid dissolves it producing a reddish violet solution. It imparts a violet-red shade to wool from an acid bath and darkish violet-red shade from the hydrosulphite vat. (Found : C, 47.3 ; H, 1.52.  $C_{16}H_5O_6N_3ClS$  requires C, 47.58 ; H, 1.49 per cent).

*7:7'-Dichlorothioindigo*.—7-Chloro-3-hydroxythionaphthene (1.988 g.) was dissolved in sodium hydroxide solution (50 c. c., 10% approx.) and warmed on the water-bath and treated slowly with a solution of potassium ferricyanide (5%) until the precipitation of the symmetrical violet-red dye was complete (1.455 g., 79.8%). It was crystallised from nitrobenzene in long pointed needles melting above 320°. It is soluble in nitrobenzene, moderately soluble in xylene and sparingly soluble in acetic acid, carbon tetrachloride and benzene ; insoluble in alcohol. It dyes wool in light violet-red shade, although not fully developed from an acid bath and cotton in pleasant violet-red shade from the deep yellow alkaline hydrosulphite vat. (Found : S, 17.0, 17.6.  $C_{16}H_6O_2Cl_2S_2$  requires S, 17.54 per cent).

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## DURABILITY OF SODA-LIME-SILICATE GLASSES. PART I.

BY AMALENDU CHOUDHURY AND H. N. DAS-GUPTA

The variation of durability of glasses with different compositions and the effect of minute traces of impurities present in the materials on the durability have been studied. A suitable range through which the compositions of the glasses may be varied without seriously impairing durability has been worked out. It has been established that for identical durability a number of glass compositions is possible.

The evil effects of glass ware of low durability have been reported by various workers (Richmond, *Analyst*, 1923, 48, 260 ; Bodenstein, *Z. physikal. Chem.*, 1894, 13, 116 ; Kooij, *ibid.*, 1893, 12, 155 ; Berthelot, *Compt. rend.*, 1897, 125, 271 ; 1905, 140, 1286 ; Mellor, "Chemical Statics and Dynamics", 1904, p. 57 ; Bone and Wheeler, *J. Chem. Soc.*, 1902, 81, 538). Poor durability of glass is primarily due to imperfect composition of the batch mixture. A simple stable glass usually contains silica, an alkaline oxide and a stabilising dibasic or a tribasic oxide. Many attempts have been made to find out the best ratio between the oxides in glass in order to obtain maximum durability (Travers, *J. Soc. Glass Tech.*, 1921, 5, 200 ; Knapp, *ibid.*, 1926, 10, 294 ; Peddle, *ibid.*, 1921, 5, 195 ; Hodkin and Turner, *ibid.*, 1920, 4, 120). Also, many formulae have been advanced to represent the best durable glass, but, the formula,  $6\text{SiO}_2 \cdot \text{R}'_2\text{O} \cdot \text{R}''\text{O}$  (where  $\text{R}'\text{O}$  represents a molecule of either sodium oxide or potassium oxide and  $\text{R}''\text{O}$ , a molecule of any of the dibasic oxides) advanced by Benrath (Peddle, "Defects in Glass", p. 205, 1927) has received wide attention as being the most suitable for soda-lime glasses. According to Benrath's formula, a soda-lime-silica glass should have 75.4% silica, 12.9% sodium oxide and 11.7% calcium oxide. The compositions of commercial soda-lime-silica glasses of standard durability approximate very closely to the values calculated above. This no doubt lends strong support in favour of Benrath's formula for a tri-silicate glass. It, however, appears erroneous to accept the above as a general formula for various reasons. Firstly, the durability of glass, as pointed out previously, is a function of the percentages of the constituent oxides, and this may be expressed mathematically as,  $D = [(\% \text{R}'_2\text{O})(\% \text{R}''\text{O})(\% \text{SiO}_2)]$ , where D stands for durability.

It follows from mathematical analysis that it is quite reasonable to obtain the same fixed value for "D" by properly varying the variables. This aspect of the problem, which is of fundamental importance, seems to have been overlooked by Benrath. Secondly, there will hardly be any uniformity in respect of durability between two glasses, prepared according to Benrath's formula, if materials of commercial quality and chemically pure ingredients be used. Thirdly, glasses containing 75.4% silica are liable to develop "silica devitrification stones", more particularly during working with these glasses (Knote, *Trans. Amer. Cer. Soc.*, 1912, 14, 655).

The present investigation has been undertaken with the following specific objects :

- (1) To study the variations in durability with different compositions and eventually to show that for identical durability a number of compositions is possible.
- (2) To indicate a suitable range through which the composition may be varied without seriously affecting the durability. According to Benrath's formula, a single com-

position will give a durable glass, but it is not often practicable to adhere strictly to a definite composition, as slight variations must take place even in the same factory owing to diverse reasons.

(3) To study the effects of minute impurities associating the raw materials and those derived from the pots or tanks. It may be pointed out at this stage that these impurities, even in minute traces, contribute substantially towards the formation of a more durable glass.

Four series of soda-lime-silica glasses were melted and in each series percentage of silica was kept constant, while successive amounts of  $\text{Na}_2\text{O}$  were replaced by lime. While selecting a composition due consideration was made regarding the possibility of founding the glass under commercially attainable furnace temperature and each specimen was prepared, as far as practicable, under identical conditions.

In order to test the durability of glasses recourse was taken to 'Powder test' (Faraday, *Phil. Trans.*, 1830, p. 49; Pelouze, *Compt. rend.*, 1856, 43, 117; Mylius and Foerster *Ber.*, 1889, 22, 1092; *Z. Instrum.*, 1889, 9, 120; Hagmaier, *Met. Chem. Eng.*, 1917, 16, 604; Nicolardot, *Compt. rend.*, 1919, 169, 335; Peddle, *J. Soc. Glass Tech.*, 1920, 4, 3, 299; 1921, 5, 72, 195). According to Peddle (*loc. cit.*) this test is of special value in working out a new glass, when the durabilities of a series of 'like' glasses have to be examined; as it shows in a remarkable manner the effect of the substitution of known amounts of a given constituent upon durability. The results of 'Powder test' are expressed in mg. of sulphuric acid required to neutralise the filtrate after boiling 100 g. of glass powder of 160 mesh sieve. Only on special occasions 'Autoclave test' (Lesure, *J. Pharm. chim.*, 1910, 1, 66; Nicolardot, *Compt. rend.*, 1916, 163, 355; Bischofsky, *J. Amer. Cer. Soc.*, 1920, 3, 296; Baillie and Wilson, *J. Soc. Glass Tech.*, 1922, 6, 279; *J. Inst. Chem.*, 1920, p. 202), as also fuming hydrochloric acid test (Walker, *J. Amer. Chem. Soc.*, 1905, 27, 865; Nicolardot, *loc. cit.*, Turner, *J. Soc. Glass Tech.*, 1917, 1, 153; 1918, 2, 219; 1919, 3, 228) were also applied.

An interesting phenomenon was observed in connection with the determination of sulphuric acid value. If the glass powder left after the acid value determination be exposed to atmosphere for overnight, it again gives a sulphuric acid value. This is more pronounced with glasses rich in  $\text{Na}_2\text{O}$ . This aspect of the problem, however, is under investigation.

#### EXPERIMENTAL

Each batch was intimately mixed and its quantity was so adjusted as to yield 100 g. of finished glass. For each melt a separate Morgan fire-clay crucible was used. The crucible was at first introduced empty in a furnace and maintained at a temperature of  $1350^\circ \pm 25^\circ$ . The batch was introduced when the crucible attained the furnace temperature and the heating was continued till the metal was almost plained. At this stage the crucible with its contents was allowed to cool slowly in the furnace. This procedure facilitates observation of the tendency of the glass towards devitrification. When cold, the crucible was broken and the glass taken out.

Table I shows the purity of the raw materials used and Table II gives the compositions of the glasses studied.

TABLE I

Material.	Source.	SiO <sub>2</sub> .	Fe <sub>2</sub> O <sub>3</sub> .	Al <sub>2</sub> O <sub>3</sub> .	CaO.	MgO.	Na <sub>2</sub> CO <sub>3</sub> .	NaCl & Na <sub>2</sub> SO <sub>4</sub> .	Loss.
Sand	Banda, (Allahabad)	98.9%	0.2%	0.2%	Slight trace	Slight trace	—	—	0.5%
Lime	Katni	3.1%	0.9%	2.1%	65.3%	0.2%	—	—	—
Heavy soda ash	L. C. I.	—	—	—	Slight trace	Slight trace	96.8%	Trace	3.1%

TABLE II

Series.	Batch No.	Batch mixture (in g.)			% Composition.			Calculated in the form of a mol. formula representing Na <sub>2</sub> O as unity.			Remarks
		Sand.	Soda.	Lime.	SiO <sub>2</sub> .	Na <sub>2</sub> O.	CaO.				
A	{ 1	73.66	34.09	18.35	73	15	12	Na <sub>2</sub> O. 0.89	CaO. 5.07	SiO <sub>2</sub>	Clear, no devitrification
	{ 2	73.66	31.81	19.9	73	14	13	Na <sub>2</sub> O. 1.03	CaO. 5.4	SiO <sub>2</sub>	Do
	{ 3	73.66	29.54	21.4	73	13	14	Na <sub>2</sub> O. 1.2	CaO. 5.85	SiO <sub>2</sub>	Do
	{ 4	73.66	28.4	22.2	73	12.5	14.5	Na <sub>2</sub> O. 1.29	CaO. 6.04	SiO <sub>2</sub>	Do
	{ 5	73.66	20.72	23.73	73	11.5	15.5	Na <sub>2</sub> O. 1.5	CaO. 6.57	SiO <sub>2</sub>	Do
	{ 6	73.66	18.01	26.03	73	10	17	Na <sub>2</sub> O. 1.88	CaO. 7.55	SiO <sub>2</sub>	Slight seedlings
	{ 7	73.66	14.33	28.33	73	8	19	Na <sub>2</sub> O. 2.61	CaO. 9.35	SiO <sub>2</sub>	Did not melt clearly
	{ 8	73.66	14.33	28.33	73	8	19	Na <sub>2</sub> O. 2.61	CaO. 9.35	SiO <sub>2</sub>	Clear, no devitrification
	{ 9	73.66	29.72	16.07	73	16.5	10.5	Na <sub>2</sub> O. 0.7	CaO. 4.57	SiO <sub>2</sub>	Do
	{ 10	73.66	31.53	14.54	73	17.5	9.5	Na <sub>2</sub> O. 0.6	CaO. 4.31	SiO <sub>2</sub>	Do
	{ 11	73.66	33.33	13.01	73	18.5	8.5	Na <sub>2</sub> O. 0.5	CaO. 4.05	SiO <sub>2</sub>	Do
B	{ 12	70.77	31.53	19.14	70	17.5	12.5	Na <sub>2</sub> O. 0.8	CaO. 4.13	SiO <sub>2</sub>	Do
	{ 13	70.77	28.8	21.4	70	16	14	Na <sub>2</sub> O. 0.96	CaO. 4.48	SiO <sub>2</sub>	Do
	{ 14	70.77	27.0	23.0	70	15	15	Na <sub>2</sub> O. 1.1	CaO. 4.83	SiO <sub>2</sub>	Do
	{ 15	70.77	22.5	26.8	70	12.5	17.5	Na <sub>2</sub> O. 1.54	CaO. 5.77	SiO <sub>2</sub>	Do
C	{ 16	74.8	31.8	13	74	17.5	8.5	Na <sub>2</sub> O. 0.53	CaO. 4.37	SiO <sub>2</sub>	Do
	{ 17	74.8	29.09	15.3	74	16	10	Na <sub>2</sub> O. 0.7	CaO. 4.77	SiO <sub>2</sub>	Do
	{ 18	74.8	27.09	16.84	74	15	11	Na <sub>2</sub> O. 0.81	CaO. 5.11	SiO <sub>2</sub>	Do
	{ 19	74.8	22.7	20.68	74	12.5	13.5	Na <sub>2</sub> O. 1.1	CaO. 6.13	SiO <sub>2</sub>	Do
D	{ 20	75.8	31.8	11.5	75	17.5	7.5	Na <sub>2</sub> O. 0.47	CaO. 4.43	SiO <sub>2</sub>	Slight seedlings
	{ 21	75.8	29.09	13.8	75	16	9	Na <sub>2</sub> O. 0.62	CaO. 4.84	SiO <sub>2</sub>	Do

The sulphuric acid value of each specimen was determined separately in accordance with the specification given under "Powder test" (*loc. cit.*). Only in a few cases the 'autoclave' and the 'fuming hydrochloric acid' tests were performed. Table III shows the results thus obtained, and it also indicates the effect of substitution of known amounts of Na<sub>2</sub>O by lime on durability. It is to be noted that the proportion of Na<sub>2</sub>O can only be decreased up to a minimum beyond which the glass becomes too much refractory. For the sake of comparison, the sulphuric acid values of Pyrex glass, 'Sico' glass, 'Sigcol' glass and a specimen of Indian bottle glass have also been included in the table.

It may be pointed out that resistant glass for chemical ware gives with the "powder test", a sulphuric acid value of about 100. A good soda-lime-silica glass gives a value about 600 (Peddle, "Defects in Glass", p. 195). On this basis it will be evident from Table III that with the exception of sample A-11, C-16 and D-20, all other samples are durable glasses. For the sake of convenience the compositions of the durable glasses have been

represented in Fig. 1 by a tri-axial diagram and any composition within the area of the rectangle will give a durable glass.

FIG. 1.

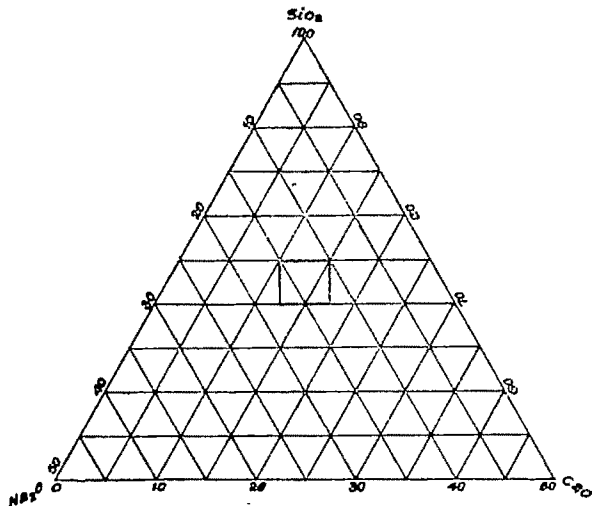


TABLE III

Series.	Batch No.	H <sub>2</sub> SO <sub>4</sub> value.	Loss in wt. after refluxing with HCl.	pH of aq. extract after autoclaving.
A	{ 1	235		
	{ 2	225		
	{ 3	186	1.5%	
	{ 4	154		
	{ 5	119	2	
	{ 6	93		8.6
	{ 9	320	2.9	
	{ 10	578	3.4	
	{ 11	879		
B	{ 12	479	3.7	
	{ 13	399	2.2	
	{ 14	303	2.2	9.0
	{ 15	164	2.5	
C	{ 16	783	3.7	
	{ 17	506	3.1	
	{ 18	290	2.3	
	{ 19	156	2.1	8.0
D	{ 20	753		10.0
	{ 21	580		
Pyrex glass		24		
'Sigcol' glass		33		
'Sico' glass (Germany)		29		
Indian glass bottle		1160		

With a view to establishing our primary object recourse has been taken to the graphic method. Figure 2 is a graphic representation of the results shown in Table III. Four curves have been obtained by plotting H<sub>2</sub>SO<sub>4</sub> values against the % Na<sub>2</sub>O of each series, as the durability of glass depends more particularly on its alkali content. In order to

ascertain the composition of the glass corresponding to any point on these curves, the silica content is directly read off from the curve, the  $\text{Na}_2\text{O}$  content is obtained from the abscissa of the point and the  $\text{CaO}$  content is obtained by difference. Now, if from a point on the ordinate, corresponding to a particular  $\text{H}_2\text{SO}_4$  value, a straight line be drawn parallel to the abscissa, this line will cut the curves at different points. The  $\text{H}_2\text{SO}_4$  value of the glasses of compositions corresponding to these points should be identical and in this way any number of lines of equal durability may be drawn from the ordinate. This line of equal durability is analogous to the line of equal melting temperature (isotherms) of Morey and Bowen (*J. Soc. Glass Tech.*, 1925, 9, 226) and to lines of equal viscosity (log isokoms of Washburn, Shelton and Libman, Bull. University of Illinois, No. 140, April 14, 1924).

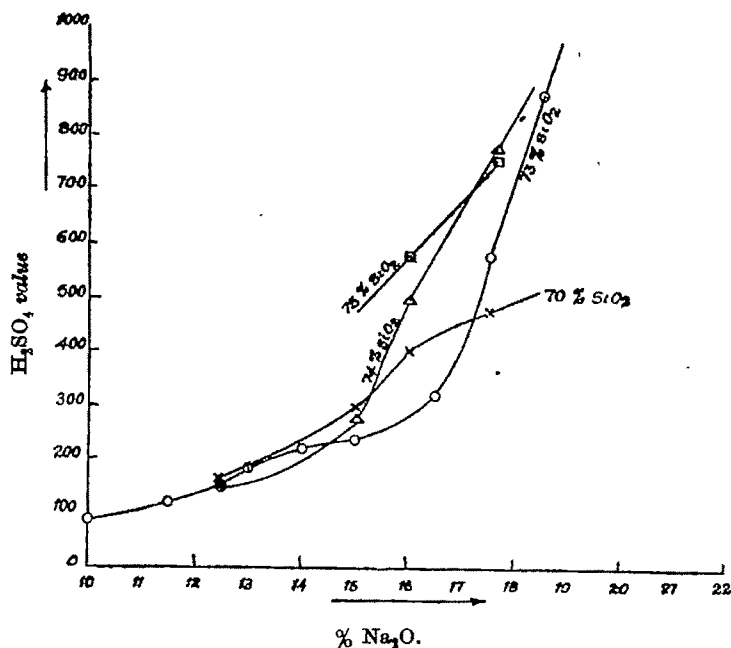


FIG. 2.

In order to substantiate the above deduction it may be pointed out that if a line be drawn from the point corresponding to a  $\text{H}_2\text{SO}_4$  value of 580, it will cut the curves at three points. The compositions of the glasses corresponding to two of these points are already known (Batch Nos. A-10 & D-21). The  $\text{H}_2\text{SO}_4$  values, as actually found out, are 578 and 580 respectively. The same identity will be found with batches bearing Nos. A-4 and C-19. Again, Table IV shows the calculated compositions of glasses corresponding to an acid value of 400 (Fig. 2) and to values actually determined. Further work in this direction is in progress.

% Composition			Acid value	
$\text{SiO}_2$	$\text{Na}_2\text{O}$	$\text{CaO}$	Calc.	Observed.
70	16	14	400	399
73	17	10	400	404
74	15.6	10.4	400	401



In order to study the effect of impurities on durability of glass, soda-lime-silica glasses of another series were melted, starting with pure ingredients. In the present case reagent quality anhydrous sodium carbonate, precipitated chalk and purified sand were used. The quantity of each batch was so adjusted as to yield 25 g. of finished glass and this was melted in a platinum crucible under identical conditions. For the sake of a comparative study the compositions were selected from those given in Table II. The glasses were then subjected to 'powder test'. It will be clear from Table V that the impurities, even in minute traces, exert a considerable influence on the durability of glass. The sulphuric acid value is almost double in each case.

TABLE VI

Batch No.	% Composition.			$H_2SO_4$ value of glass from	
	$SiO_2$ .	$Na_2O$ .	$CaO$ .	commercial material.	pure material
A-1	73	15	12	235	408
B-14	70	15	15	303	817
C-17	74	16	10	506	793
D-21	75	16	9	580	1038

## DISCUSSION

From Fig. 2 it is evident that each curve has a steep portion of its own. This indicates how rapidly the durability changes with change of  $Na_2O$  content and after this the rate of change is not very appreciable. The various compositions corresponding to the steep portion of each curve will be of special advantage to glass manufacturers. Because, in order to take the best advantage of decreasing alkali content, without at the same time impairing appreciably the melting and working qualities of glass, the manufacturer can utilise any composition represented by the steep portion of the curves. The composition, however, is to be so selected as to yield a glass of low sulphuric acid value.

Secondly, the lines of equal durability will offer to the manufacturers a number of possible compositions for founding a glass of desired durability. From these they will be able to select a particular composition consistent with the furnace efficiency and with the viscosity required in working the metal.

The effect of impurities on durability of glass is evident from Table V. It is sufficiently clear that a dibasic oxide alone cannot confer a desired durability on a simple glass consisting of silica and an alkaline oxide. The presence of a slight trace of a tri-basic oxide is essential.

Lastly, referring to the different tests in vogue for testing the durability of glass it is claimed that though these tests give different values they, however, follow the same order. But from our findings we could not corroborate the statement.

Received May 12, 1947.

# THE VARIATION OF SPECIFIC CONDUCTIVITY WITH TEMPERATURE

BY RAM GOPAL

A study of the variation of specific conductivity,  $\mu$  with temperature,  $t$  in concentrated aqueous solutions, both above and below the saturation temperature, shows that while  $\mu$ - $t$  curves for viscous solutions have a positive curvature and obey the Kohlrausch's equation viz.,  $\mu_t = \mu_0(1 + \alpha t + \beta t^2)$ , those for solutions of low viscosity are almost straight lines and obey the equation of Walden viz.,  $\mu_t = \mu_0(1 + \alpha t)$ .

The behaviour of the latter is in contradiction with Heim's observations on a number of supersaturated aqueous solutions and as the study in this paper is confined to such solutions, an explanation, depending upon the ionic hydration hypothesis and the concept of depolymerisation of water molecular complexes, is suggested to account for this anomaly.

The variation of specific conductivity with temperature has been studied by a number of workers specially by Gotrain, Arrhenius, Deguisne and others. From the observations of Deguisne (Dissertation, Strassburg, 1893), Kohlrausch (*Sitz. Preuss. Akad. Wiss.*, 1901, 42, 1028) suggested that the variation of  $\mu$  with temperature  $t$ , in very dilute solutions ( $N/100$  and  $N/1000$ ) of HCl,  $K_2SO_4$ ,  $BaCl_2$ , KOH, KCl,  $KNO_3$ ,  $Ba(NO_3)_2$ ,  $NaNO_3$  and Na acetate etc., can be represented by

$$\mu_t = \mu_0(1 + \alpha t + \beta t^2) \dots (1)$$

Heim (*Ann. Physik*, 1886, 27, 643) showed this equation to hold in a number of solutions, both above and below the temperature of saturation. Bousefield and Lowery (*Proc. Roy. Soc.*, 1903, 71, 42), Kunz (*Z. physikal. Chem.*, 1903, 42, 591) demonstrated that the equation (1) held only within a certain range of temperatures and beyond this range  $\mu$ - $t$  curves did not follow the course predicted by this equation and approached the temperature axis asymptotically. Hence any conclusion arrived at below this range on the basis of the equation would lead to erroneous conclusions (cf. Prakash, *J. Phys. Chem.*, 1933, 37, 907; Musharan and Prakash, *ibid.*, 1946, 50, 251).

Walden (*Z. physikal. Chem.*, 1910, 73, 257) from his study of this problem in non-aqueous media down to very low temperatures (in some cases as low as  $-100^\circ$ ) found that most of his results above zero degree could be expressed by a simple linear equation,

$$\mu_t = \mu_0(1 + \alpha t) \dots (2)$$

Worshoven (*ibid.*, 1890, 5, 581) found equation (2) applicable to some of the concentrated solutions of cadmium salts.

In connection with some work on supersaturation, specific conductivity of a number of highly concentrated and supersaturated aqueous solutions was studied and that offered an opportunity to examine the applicability of these equations and also to ascertain whether Heim's conclusions are so general as to admit applicability of the equation of Kohlrausch to all the supersaturated solutions.

## EXPERIMENTAL

The measurement of conductivity was carried out in the usual way using a cell having a high cell constant, similar to that of Jones and Bickford (*J. Amer. Chem. Soc.*, 1934, 56, 604) and made of pyrex glass and of about 10 c.c. capacity in order to avoid the use of a large amount of chemicals. Although, in general, five concentrations were studied,  $\mu$  values corresponding to only one concentration have been shown in Table I to economise space. From the data  $\mu$ - $t$  curves have been plotted and some typical ones are shown in Figs. 1 and 2.

TABLE I  
Specific conductivity ( $\mu$ ) at different temperatures.

Substance.	Conc.* (Sw 100)	30°.	35°.	$\mu \times 10^3$ at 40°.	45°.	50°.	55°.	60°.
KCl	38.7	43.68	46.57	49.46	52.52	55.60	58.40	—
KBr	73.5	47.49	50.26	53.03	56.10	58.98	61.97	—
KNO <sub>3</sub>	54.01	28.20	30.25	32.48	34.61	36.52	38.80	—
KIO <sub>3</sub>	11.60	4.380	4.790	5.190	5.62	6.02	6.441	—
KClO <sub>3</sub>	12.29	9.335	10.13	10.86	11.70	12.42	13.20	—
NaNO <sub>3</sub>	102.5	21.27	23.54	25.69	27.89	30.20	32.56	34.95
NaClO <sub>3</sub>	118.0	17.22	19.05	20.29	22.86	24.89	26.97	—
NH <sub>4</sub> Cl	43.8	—	57.36	60.67	63.90	67.31	70.98	—
NH <sub>4</sub> NO <sub>3</sub>	270.0	34.02	36.31	38.67	41.18	43.68	46.31	—
KCNs	286.0	—	24.02	26.41	28.37	30.72	32.56	34.52
Na acetate	59.96	7.295	8.410	9.781	11.06	12.52	13.90	—
K acetate	250.0	4.602	5.550	6.382	7.465	8.58	9.724	10.78
K <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	44.38	27.85	29.84	32.20	34.11	36.70	38.69	—
(NH <sub>4</sub> ) <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	9.62	9.664	10.62	11.35	12.20	13.08	13.94	—
K <sub>2</sub> SO <sub>4</sub>	14.01	12.78	14.02	14.90	15.04	16.02	17.95	—
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	80.04	29.43	31.94	34.31	36.84	39.40	41.75	—
K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	21.69	12.98	13.88	15.15	16.10	17.18	18.21	—
Ba(NO <sub>3</sub> ) <sub>2</sub>	12.70	5.690	6.238	6.810	7.445	8.039	8.648	—
BaCl <sub>2</sub>	40.70	20.67	22.40	24.02	25.71	27.41	29.12	—
Pb(NO <sub>3</sub> ) <sub>2</sub>	69.83	10.23	12.27	12.39	13.51	14.62	15.68	16.86
CuSO <sub>4</sub>	33.46	6.387	7.562	8.271	8.948	9.724	10.37	11.12
MgSO <sub>4</sub>	45.76	3.602	4.020	4.583	5.162	5.790	6.369	—
H <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	17.66	13.47	14.01	14.69	15.35	15.81	16.42	16.89
K <sub>3</sub> Fe(CN) <sub>6</sub>	33.60	22.68	24.45	26.14	27.89	29.74	31.28	—

\* Concentration is expressed in grams of solute in 100 g. of water.

## DISCUSSION

From the Figs. 1 and 2 it appears that except for oxalic acid, the curves fall into two distinct categories. To the first category in which the curves are almost linear,

FIG. 1.

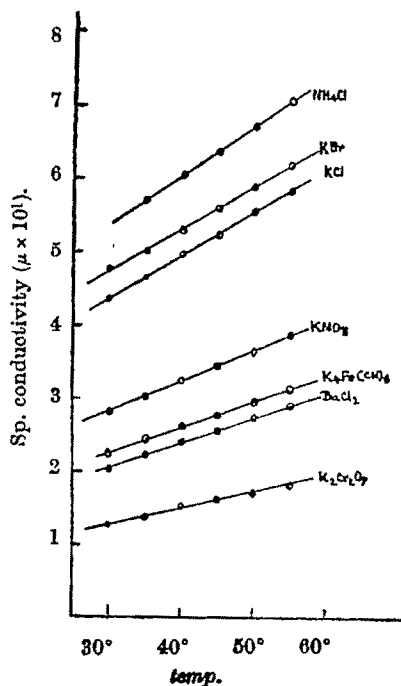
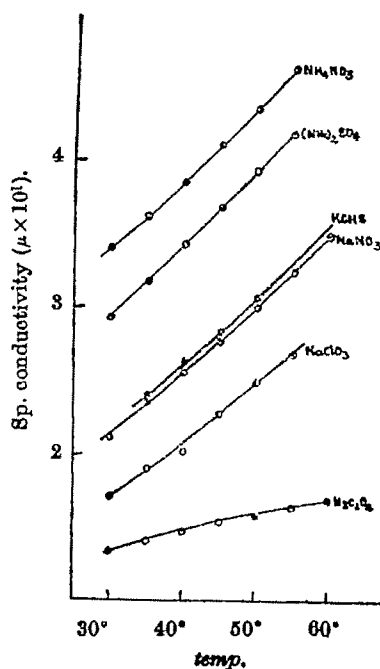


FIG. 2.



belong most of the solutions with low viscosity e.g., solutions of KCl, KBr,  $\text{KNO}_3$ ,  $\text{NH}_4\text{Cl}$ , etc. In such solutions therefore the equation (2) of Walden will hold at least within the temperature range studied here. Obviously in these case  $\partial\mu/\partial t$  is a constant.

In the second category,  $\mu$ - $t$  curves are not linear but have more or less a positive curvature (Fig. 2). The solutions have comparatively a high viscosity than those of the first category. This class includes the solutions of  $\text{NaNO}_3$ ,  $\text{NaClO}_3$ , KCNS, Na and K acetates,  $\text{MgSO}_4$ , etc. In general, higher the viscosity, greater the curvature, i.e. greater the value of the temperature coefficient  $\partial\mu/\partial t$ . In these cases the equation (1) of Kohlrausch will be applicable. It is therefore the substances of the second category which behave similarly to those examined by Heim. To the substances of the first category Heim's conclusions will not be applicable.

As the range of applicability of these equations is very much limited, no useful purpose will be served by a further detailed study of these equations. However, an explanation is evidently desirable to account for the anomalous behaviour of the solutions of the first category as, according to Kohlrausch and others, dilute aqueous solutions obey the quadratic law in numerous cases at ordinary temperatures and according to Heim, concentrated and supersaturated solutions are also governed by the same rule.

According to Jone and Jacobson (*Amer. Chem. J.*, 1908, 40, 555), departure from the straight line nature of the  $\mu$ - $t$  curves is due to the lowering of the hydration of ions as a result of rise in temperature. This lowering in hydration increases the mobility of ions, over and above that due to increase in kinetic energy as a result of the rise in temperature, and this lowering will be greater, the higher the temperature. Then the  $\mu$ - $t$  curves will naturally assume a positive curvature. Besides, the depolymerisation of water molecular complexes, resulting in a lowering in viscosity, which will be greater, the higher the temperature, will add to this effect and in all dilute solutions therefore the curves will have their  $\partial\mu/\partial t$  positive. It appears very probable that the observations of Deguise and others in dilute solutions are mostly due to depolymerisation of water molecular complexes at higher temperatures.

When an electrolyte is dissolved in water, it is well known that it causes a depolymerisation of water molecular complexes and it may eventually change most of them into simple  $\text{H}_2\text{O}$  molecules at very high concentrations. At lower concentrations all the ions are individually hydrated to the maximum, depending upon their attraction for  $\text{H}_2\text{O}$  molecules and also majority of water molecular complexes will be present excepting a few which have been depolymerised due to the effect of the solute. This will result in a rise of specific conductivity with temperature in the manner discussed above.

As the concentration is further raised, more depolymerisation of water molecular complexes occurs and hydration of individual ions goes on diminishing. If an ion in question has a very small tendency for hydration e.g.,  $\text{K}^+$ ,  $\text{Rb}^+$ ,  $\text{Cs}^+$ ,  $\text{NO}_3^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$ , and  $\text{Cl}^-$  etc., a stage will be reached at a sufficiently high concentration, when nearly all the water complexes will be depolymerised, and also hydration of individual ions will be almost negligible. Such solutions will have a very low viscosity inspite of high concentration. Hence, rise in the value of specific conductivity with temperature in these cases will be, in the main, solely due to the increase in the kinetic energy of the almost unhydrated ions. Hence curves would be linear in these cases as is borne out

by experiments. It is very likely that if the temperature is very much lowered, some slight curvature in  $\mu$ - $t$  curves may be found, as at lower temperatures hydration will play a more important role.

However, if the ions concerned have a great affinity for water molecules, the environments will be quite different. Although water molecular complexes will be slowly depolymerised, these will be replaced by heavily hydrated ions as the concentration rises. Due to high hydration, the lowering in the hydration of individual ions, as a result of the rise in concentration, will not affect the outcome much, and the majority of the water molecules will be bound up with the solute ions in some way or other. Hence, as has been discussed above,  $\mu$ - $t$  curves have a positive curvature and they obey a quadratic law.

The  $\mu$ - $t$  curves for oxalic acid do not belong to any of the two categories mentioned in the foregoing pages, and have a negative curvature (Fig. 2). Although  $\mu$  still increases with  $t$ ,  $\partial\mu/\partial t$  is negative. This phenomenon has been studied by Watson and Jones (*Amer. Chem. J.*, 1911, 46, 368), Usanovitsch (*Compt. rend. U. S. S. R.*, 1939, 25, 608) and others. Probably this phenomenon is closely connected with the low degree of dissociation of the acid and decreasing dielectric constant of the medium with rising temperature which will still lower the degree of dissociation of the acid (cf. Davies, "Conductivity of Solutions", 1930, p. 126).

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PHYSICO-CHEMICAL STUDIES ON THE COMPOSITION OF COMPLEX  
METALLIC FERRO AND FERRICYANIDES. PART I. COMPOSITION  
OF COPPER FERROCYANIDE BY THERMOMETRIC METHOD

BY ABANI K. BHATTACHARYA AND HARISH C. GAUR

Composition of copper ferrocyanide has been investigated by thermometric method. From the breaks in the direct titration curves, the compound  $K_2CuFeCy_6$ , first formed with excess of  $CuSO_4$ , changes to  $K_4Cu_3(FeCy_6)_2$ .

The composition of copper ferrocyanide has been investigated by several workers both by purely analytical methods and by physico-chemical methods. But there is hardly any co-ordination of the views expressed by them. Wyrubow (*Ann. chim. phys.*, 1905, *viii*, 5, 444) prepared three compounds corresponding to  $Cu_2FeCy_6$ ;  $K_2CuFeCy_6$ ,  $K_4FeCy_6$  and  $KCuFeCy_6$  under varying conditions. Müller, Wegelin and Kellerhoff (*J. prakt. Chem.*, 1912, *ii*, 86, 82) investigated the composition of the precipitates formed by the interaction of copper sulphate with potassium ferrocyanide, and with hydroferrocyanic acid, in various proportions in 0.1M- aqueous solutions, and they were of the opinion that a precipitate of a constant composition could be obtained only when one of the two components was in large excess. For the intermediate values of the ratio  $CuSO_4/K_4FeCy_6$ , several compounds of variable compositions were obtained. Williams ("The Chemistry of Cyanogen Compounds", pp. 103-104) found that the compounds  $K_4Cu_4(FeCy_6)_3$  was formed when potassium ferrocyanide was precipitated exactly by a cupric salt. In the presence of a large excess of potassium ferrocyanide the precipitate corresponded to  $K_{10}Cu_7(FeCy_6)_6$ , while in the presence of a large excess of copper salt, the composition of the precipitate was found to be  $K_2Cu_6(FeCy_6)_3$ . Rauter (*Z. angew. Chem.*, 1895, 8, 315) was of the opinion that copper ferrocyanide adsorbed some potassium ferrocyanide, and due to the colloidal nature of the precipitate it peptised before it could be washed entirely free of it. This suggested that purely analytical methods could not be of much use in determining the composition of copper ferrocyanide.

Kolthoff (*Z. anal. Chem.*, 1923, 62, 209) employing the method of conductometric titrations observed that at first the normal salt,  $Cu_2FeCy_6$  was precipitated, which with further quantity of the reagent formed the double salt  $K_2Cu_3(FeCy_6)_2$ , followed by a third inflection point corresponding to the formation of  $K_4Cu_4(FeCy_6)_3$ . But Britton and Dodd (*J. Chem. Soc.*, 1933, 1543) following the same method did not confirm these results; they obtained two inflections corresponding to the formations of  $Cu_2FeCy_6$ ,  $xK_4FeCy_6$ , where  $x=0.16$  and 0.40.

In view of the conflicting opinions it was considered worthwhile to study the composition of this compound by thermometric, conductometric and potentiometric methods to arrive at a more definite conclusion. In this paper only the results of thermometric titrations have been included and discussed.

EXPERIMENTAL

The thermometric titration arrangement was similar to that adopted by Haldar (*J. Indian Chem. Soc.*, 1946, 23, 147). The reagents used were of 'Analar' (B. D. H.) quality.

Standard solution of copper sulphate was prepared by direct weighing. Potassium ferrocyanide solution was estimated by titrating against standardised potassium permanganate solution (Treadwell and Hall, "Analytical Chemistry", Part II, p. 536).

Using the different concentrations of the two salts in solutions the titrations were followed by the direct and the reverse methods, i. e. when copper sulphate solution from burette was added to potassium ferrocyanide taken in the Dewar flask and *vice versa*. Titrations were also carried in the presence of alcohol, up to the total concentration of 20% by volume.

A/1-Copper sulphate solution (containing 31.344 g.  $\text{CuSO}_4$  per litre) corresponds to  $M/5.09$  solution. A/1-Potassium ferrocyanide solution (containing 84.494 g. of  $\text{K}_4\text{FeCy}_6$ ,  $3\text{H}_2\text{O}$  per litre) corresponds to  $M/5.0$  solution.

#### Direct Thermometric Titrations

Copper sulphate solution from a burette was added to potassium ferrocyanide taken in the flask, and mixed with varying amounts of alcohol.

TABLE I

A/10- $\text{K}_4\text{FeCy}_6$  soln. = 20 c. c. Alcohol = nil (Fig. 1, curve 1).

A/2- $\text{CuSO}_4$ added	Total rise in temp.	A/2- $\text{CuSO}_4$ added.	Total rise in temp.	A/2- $\text{CuSO}_4$ added.	Total rise in temp.
0.0 c. c.	0.000	3.0 c.c.	0.180	6.0 c.c.	0.330
0.5	0.030	3.5	0.210	6.5	0.345
1.0	0.060	4.0	0.230	7.0	0.355
1.5	0.090	4.5	0.255	7.5	0.365
2.0	0.120	5.0	0.280	8.0	0.370
2.5	0.150	5.5	0.305	8.5	0.385

TABLE II

A/10- $\text{K}_4\text{FeCy}_6$  soln. = 18 c. c. Alcohol = 2 c. c. (Fig. 2, curve 2).

A/2- $\text{CuSO}_4$ added.	Total rise in temp.	A/2- $\text{CuSO}_4$ added.	Total rise in temp.	A/2- $\text{CuSO}_4$ added.	Total rise in temp.	A/2- $\text{CuSO}_4$ added.	Total rise in temp.
0.0 c. c.	0.000	2.5 c. c.	0.110	4.5 c. c.	0.200	6.5 c. c.	0.260
1.0	0.030	3.0	0.130	5.0	0.225	7.0	0.265
1.5	0.050	3.5	0.155	5.5	0.240	7.5	0.270
2.0	0.075	4.0	0.180	6.0	0.255	8.0	0.275

TABLE III

A/10- $\text{K}_4\text{FeCy}_6$  soln. = 16 c. c. Alcohol = 4 c. c. (Fig. 2, curve 3).

A/2- $\text{CuSO}_4$ added.	Total rise in temp.	A/2- $\text{CuSO}_4$ added.	Total rise in temp.	A/2- $\text{CuSO}_4$ added.	Total rise in temp.
0.0 c. c.	0.000	3.0 c.c.	0.190	6.0 c.c.	0.295
0.5	0.030	3.5	0.210	6.5	0.300
1.0	0.060	4.0	0.235	7.0	0.305
1.5	0.095	4.5	0.260	7.5	0.310
2.0	0.130	5.5	0.290	8.0	0.315

TABLE IV

A/10-K<sub>4</sub>FeCy<sub>6</sub>=20 c.c. Alcohol=nil. (Fig. 3, curve 4).

A/4-CuSO <sub>4</sub> added.	Total rise in temp.	A/4-CuSO <sub>4</sub> added.	Total rise in temp.	A/4-CuSO <sub>4</sub> added.	Total rise in temp.
0.0 c. c.	0.000	8.0 c. c.	0.190	14.0 c. c.	0.340
1.0	0.020	9.0	0.220	15.0	0.355
2.0	0.045	10.0	0.250	16.0	0.370
4.0	0.100	11.0	0.275	17.0	0.380
6.0	0.155	12.0	0.300	18.0	0.395
7.0	0.180	13.0	0.325		

TABLE V

A/10-K<sub>4</sub>FeCy<sub>6</sub>=18 c.c. Alcohol=2 c.c. (Fig. 3, curve 5).

A/4-CuSO <sub>4</sub> added.	Total rise in temp.	A/4-CuSO <sub>4</sub> added.	Total rise in temp.	A/4-CuSO <sub>4</sub> added.	Total rise in temp.
0.0 c.c.	0.000	5.5 c.c.	0.240	9.5 c.c.	0.380
0.5	0.025	6.5	0.280	10.5	0.410
1.5	0.065	7.0	0.305	11.0	0.425
2.5	0.110	8.0	0.335	12.0	0.445
3.5	0.160	8.5	0.350	13.0	0.465
4.5	0.200	9.0	0.365	13.5	0.475

TABLE VI

A/10-K<sub>4</sub>FeCy<sub>6</sub>=16 c.c. Alcohol=4 c.c. (Fig. 3, curve 6).

A/4-CuSO <sub>4</sub> added.	Total rise in temp.	A/4-CuSO <sub>4</sub> added.	Total rise in temp.	A/4-CuSO <sub>4</sub> added.	Total rise in temp.
0.0 c.c.	0.000	5.0 c.c.	0.435	9.0 c.c.	0.655
1.0	0.165	6.0	0.500	10.0	0.695
2.0	0.205	7.0	0.560	11.0	0.730
3.0	0.280	8.0	0.615	12.0	0.755
4.0	0.370			12.5	0.765

*Reverse Thermometric Titrations*

Potassium ferrocyanide from a burette was added to copper sulphate solution in the Dewar flask, and mixed with varying amounts of alcohol.

TABLE VII

A/10-CuSO<sub>4</sub> soln.=20 c.c. Alcohol=nil. (Fig. 4, curve 7).

A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.
0.0 c.c.	0.000	2.5 c.c.	0.100	6.0 c.c.	0.200
0.5	0.020	3.0	0.120	7.0	0.210
1.0	0.040	3.5	0.140	8.0	0.220
1.5	0.060	4.0	0.160	9.0	0.230
2.0	0.080	5.0	0.190	9.5	0.235



TABLE VIII

A/10-CuSO<sub>4</sub> soln.=18 c.c. Alcohol=2 c.c. (Fig. 4, curve 8).

A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.
0.0 c.c.	0.000	2.5 c.c.	0.115	5.5 c.c.	0.215	7.5 c.c.	0.255
1.0	0.045	3.0	0.140	6.0	0.225	8.0	0.265
1.5	0.070	4.0	0.185	6.5	0.235	8.5	0.275
2.0	0.090	5.0	0.210	7.0	0.245	9.0	0.285

TABLE IX

A/10-CuSO<sub>4</sub> soln.=16 c.c. Alcohol=4 c.c. (Fig. 4, curve 9).

A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.
0.0 c.c.	0.000	3.0 c.c.	0.250	6.0 c.c.	0.370
1.0	0.090	3.5	0.285	7.0	0.385
1.5	0.135	4.5	0.335	7.5	0.395
2.0	0.180	5.0	0.345	8.0	0.405
2.5	0.220	5.5	0.355	8.5	0.415

TABLE X

A/10-CuSO<sub>4</sub> soln.=20 c.c. Alcohol=nil. (Fig. 5, curve 10).

A/8-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/8-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/8-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.
0.0 c.c.	0.000	5.5	0.220	10.5 c.c.	0.415
0.5	0.012	6.5	0.260	11.5	0.450
1.5	0.055	7.5	0.305	12.5	0.475
2.5	0.095	8.5	0.350	13.5	0.500
3.5	0.135	9.5	0.390	14.5	0.525
4.5	0.175			15.0	0.535

TABLE XI

A/10-CuSO<sub>4</sub> soln.=18 c.c. Alcohol=2 c.c. (Fig. 5, curve 11).

A/8-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/8-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/8-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/8-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.
0.0 c.c.	0.000	3.0 c.c.	0.105	7.0 c.c.	0.240	14.0 c.c.	0.330
0.5	0.010	4.0	0.140	8.0	0.260	12.0	0.350
1.0	0.030	5.0	0.170	9.0	0.290	13.0	0.370
2.0	0.075	6.0	0.205	10.0	0.310	14.0	0.390

TABLE XII

A/10-CuSO<sub>4</sub>=16 c.c. Alcohol=4 c.c. (Fig. 5, curve 12).

A/8-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/8-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.	A/8-K <sub>4</sub> FeCy <sub>6</sub> added.	Total rise in temp.
0.0 c.c.	0.000	5.0 c.c.	0.410	9.0	0.590
2.0	0.200	6.0	0.460	10.0	0.610
2.5	0.240	7.0	0.515	11.0	0.630
3.0	0.280	8.0	0.560	12.0	0.650
4.5	0.380			13.0	0.670

*Direct Thermometric Titrations* (curves 1-6)

TABLE XIII

(i) A/2-CuSO<sub>4</sub> and A/10-K<sub>4</sub>FeCy<sub>6</sub>

Conc. ratio (n)=5:1.

Vol of A/10-K <sub>4</sub> FeCy <sub>6</sub> in the thermos-flask (v)	Alcohol added	A/2-CuSO <sub>4</sub> reqd for K <sub>4</sub> FeCy <sub>6</sub> in the thermos (v <sub>1</sub> )		A/2-CuSO <sub>4</sub> calc for 20 c.c. of A/10 K <sub>4</sub> FeCy <sub>6</sub> (v <sub>1</sub> /v) 20		Equiv. vol of A/10-CuSO <sub>4</sub> , n (20v <sub>1</sub> /v).		Curve No
		I Break.	II Break.	I Break.	II Break.	I Break.	II Break.	
20.0 c.c.	0.0 c.c.	4.16 c.c.	6.32 c.c.	4.16 c.c.	6.32 c.c.	20.80 c.c.	31.6 c.c.	1
18.0	2.0	3.70	5.65	4.11	6.28	20.55	31.4	2
16.0	4.0	3.20	5.00	4.00	6.25	20.00	31.25	3

(ii) A/4-CuSO<sub>4</sub> and A/10-K<sub>4</sub>FeCy<sub>6</sub>

Conc. ratio (n)=2.5:1.

20.0 c.c.	0.0 c.c.	8.35 c.c.	12.6 c.c.	8.35 c.c.	12.6 c.c.	20.87 c.c.	31.5 c.c.	4
18.0	2.0	7.35	11.3	8.17	12.55	20.42	31.4	5
16.0	4.0	6.45	10.0	8.06	12.50	20.15	31.2	6

The tables show that the amount of copper sulphate required for 20 c.c. of potassium ferrocyanide decreases as the amount of alcohol is increased.

*Reverse Thermometric Titrations* (curves 7-12)

TABLE XIV

(i) A/4-K<sub>4</sub>FeCy<sub>6</sub> and A/10-CuSO<sub>4</sub>. Conc. ratio (n)=2.5:1.

Vol of A/10-CuSO <sub>4</sub> in the thermos flask (v)	Alcohol added.	A/4-K <sub>4</sub> FeCy <sub>6</sub> reqd for CuSO <sub>4</sub> in the thermos flask (v <sub>1</sub> )	A/4-K <sub>4</sub> FeCy <sub>6</sub> calc. for 20 c.c. of A/10 CuSO <sub>4</sub> (20 v <sub>1</sub> /v)	Equiv. vol of A/10-K <sub>4</sub> FeCy <sub>6</sub> , n(20 v <sub>1</sub> /v)	Curve No.
20.0 c.c.	0.0 c.c.	4.8 c.c.	4.8 c.c.	12.0 c.c.	7
18.0	2.0	4.40	4.89	12.2	8
16.0	4.0	4.0	5.00	12.5	9

(ii) A/8-K<sub>4</sub>FeCy<sub>6</sub> and A/10-CuSO<sub>4</sub>. Conc. ratio (n)=4:5.

20.0 c.c.	0.0 c.c.	10.0 c.c.	10.0 c.c.	12.50 c.c.	10
18.0	2.0	9.05	10.06	12.6	11
16.0	4.0	8.20	10.25	12.81	12

The tables show that the amount of K<sub>4</sub>FeCy<sub>6</sub> required for 20 c.c. of CuSO<sub>4</sub> increases as the amount of alcohol is increased.

## DISCUSSION

Considering the strength of the solutions of copper sulphate (*M*/5.09) and potassium ferrocyanide (*M*/5), theoretical titre values required for the 20 c.c. of K<sub>4</sub>FeCy<sub>6</sub> for the formation of the compounds K<sub>2</sub>CuFeCy<sub>6</sub>, Cu<sub>2</sub>FeCy<sub>6</sub>, and K<sub>2</sub>Cu<sub>3</sub>(FeCy<sub>6</sub>)<sub>2</sub> in direct titrations would be 20.38, 40.76, and 30.56 c.c. respectively of copper sulphate solution. For the reverse titrations, the theoretical titre values for 20 c.c. of copper sulphate

solution for the formation of the above compounds would be 19.64, 9.82, and 13.08 c.c. respectively of potassium ferrocyanide solution.

FIG. 1.

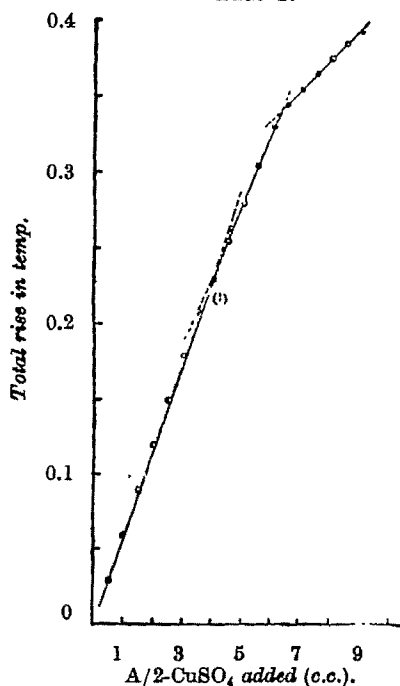
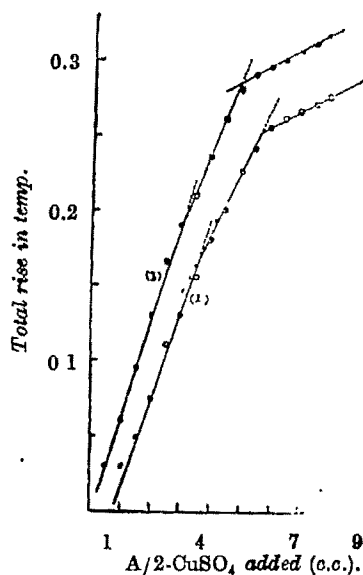


FIG. 2.



In the curves for direct titrations (Fig. 1, 2, and 3) there are two breaks and the observed titre values correspond approximately to the formation of the compounds

FIG. 3.

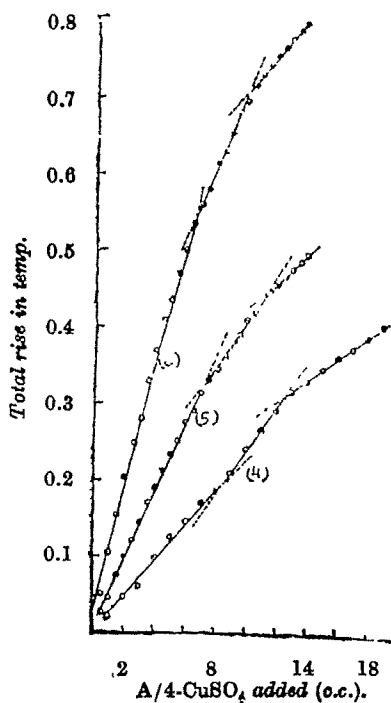
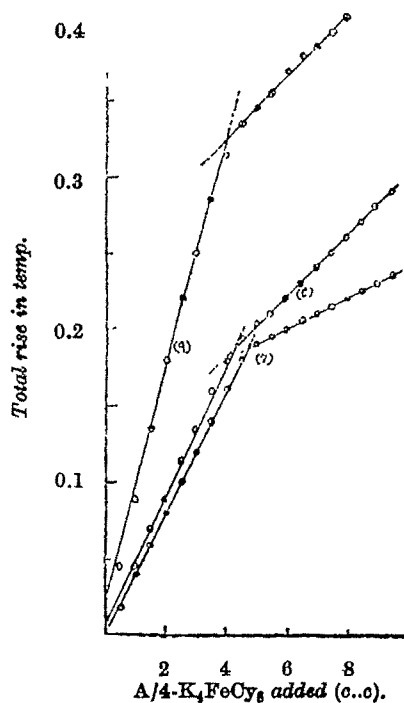


FIG. 4.



$K_2CuFeCy_6$  and  $K_2Cu_3(FeCy_6)_2$ . In the reverse case (Fig. 4 and 5), there is only one break which corresponds approximately to the formation of  $K_2Cu_3(FeCy_6)_2$ . The pure compound  $Cu_3FeCy_6$  is not formed in either of the cases.

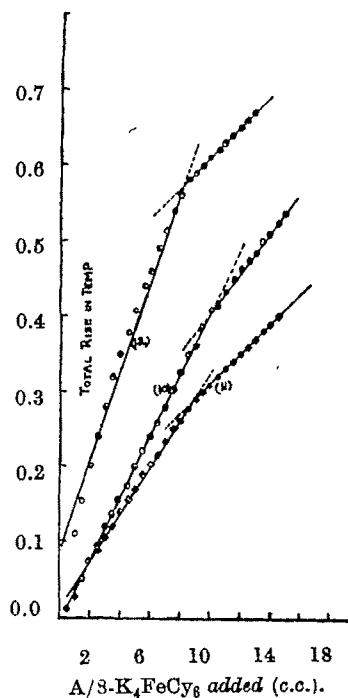
The discrepancy between the observed titre values (Tables XIII, XIV) and the theoretical ones given above, is explained on the tendency of the compound formed to hydrolyse. Then potassium ferrocyanide thus released would react with more of copper sulphate with the result that the titre values in aqueous solution would be greater in direct titrations and less in the reverse titrations than the theoretical values. The effect of addition of alcohol in increasing amounts in direct titrations is the gradual decrease in the observed titre values; in the reverse titrations, an increase is observed under the same conditions. This can be explained as due to the check of the hydrolysis of the compound. Then the observed titre values in presence of increasing amounts of alcohol should correspond more closely to the theoretical values in the direct and the reverse titrations. This has been actually observed.

The adsorption of  $Cu^{II}$  and  $[Fe(CN)_6]^{IV}$  ions by copper ferrocyanide should not, however, be altogether ignored. The effect of adsorption of these ions from the surrounding solution, by the precipitate, would be to decrease the titre values in aqueous medium in both the cases, which should then increase in the presence of alcohol. This is observed only in the reverse titrations, whereas there is a decrease in the titre value in the direct titration in presence of alcohol. This suggests that the role of hydrolysis is more predominant in the precipitation of copper ferrocyanide. This fact was ignored by previous authors and hence conflicting views on the composition of copper ferrocyanide were given.

From the breaks in the direct titration curves (Fig. 1 to 3) it appears that the compound  $K_2CuFeCy_6$  is first formed which with excess of copper sulphate changes to  $K_2Cu_3(FeCy_6)_2$ , the latter corresponding to the second break in the curves. In the reverse cases, the titration is carried in presence of excess of copper sulphate and hence the break corresponding to  $K_2CuFeCy_6$  is not observed.

Thermometric titration results support the conclusions of Kolthoff (*loc. cit.*) so far as the formation of the compounds  $K_2Cu_3(FeCy_6)_2$  is concerned. The inflection in the conductivity curves obtained by him corresponding to the formation of  $K_4Cu_4(FeCy_6)_3$  is not supported.

FIG. 5.



The work has been extended by the study of conductometric and potentiometric titrations along with hydrolysis and adsorption which will be communicated through separate papers.

Our thanks are due to Dr. S. S. Deshapande for the interest he has taken in the work. One of the authors (H. C. Gaur) expresses his gratefulness to Dr. K. C. Mehta, Principal, Agra College, for the grant of a Research fellowship.

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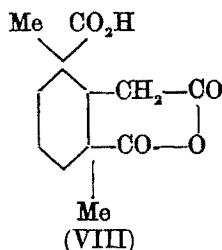
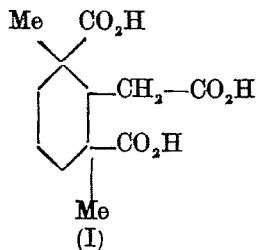
*Received May 9, 1947.*

# ON RESIN ACIDS. SYNTHESIS OF AN ANHYDRIDE OF 1:3-DIMETHYL-1:3-DICARBOXYCYCLOHEXYL-2-ACETIC ACID

BY SAILENDLA MOHAN MUKHERJEE

Diethyl 1:3-dimethylcyclohexane-2-one-1:3-dicarboxylate reacts with zinc and ethyl bromoacetate to give the corresponding hydroxy-ester, which on dehydration, catalytic reduction and subsequent hydrolysis affords the anhydride of 1:3-dimethyl-1:3-dicarboxycyclohexyl-2-acetic acid.

On energetic oxidation of abietic acid with potassium permanganate (Ruzicka *et al.*, *Helv. Chim. Acta*, 1925, 9, 637 ; 1931, 14, 545) or with nitric acid (Levy, *Ber.*, 1929, 62, 2494) a  $C_{12}$ -acid (I) has been isolated.



An attempt has been made to synthesise the above acid along the following line, but unfortunately the anhydride (VIII) obtained synthetically happens to have a melting point different from that obtained from the natural sources.

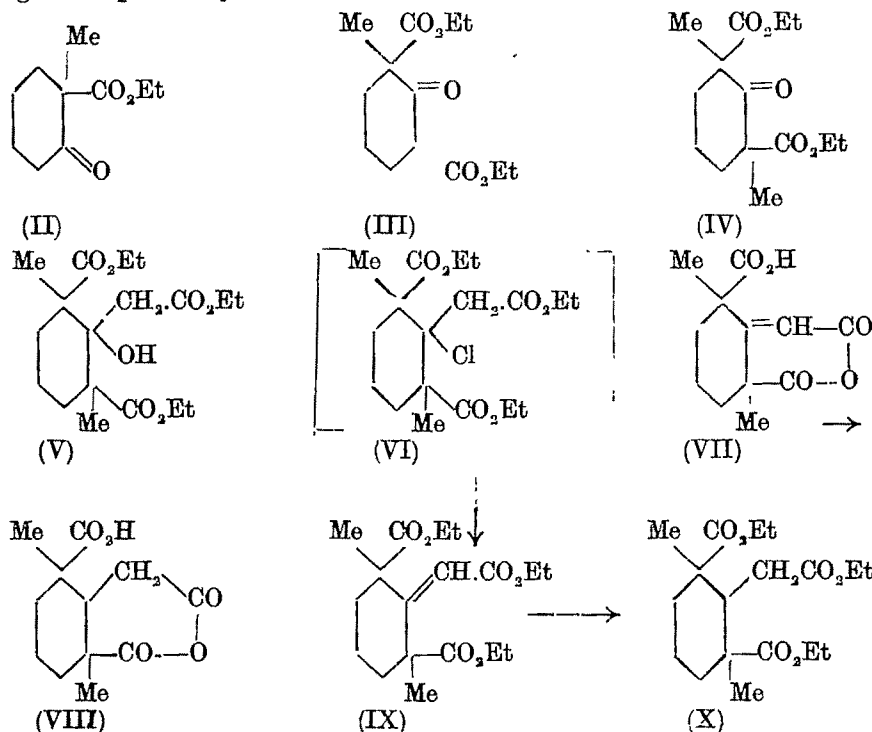
Ethyl 2-methylcyclohexanone-2-carboxylate (II) is condensed with ethyl oxalate in presence of molecular quantity of sodium ethoxide in ether (cf. Kotz and Michets, *Annalen*, 1906, 350, 212). In the present case the only precaution taken is that the temperature at which the reaction to be carried out is kept throughout the experiment below  $-10^{\circ}$ , when a satisfactory yield of the oxalo derivative is obtained which, on being heated with powdered soft glass (Bachmann *et al.*, *J. Amer. Chem. Soc.*, 1940, 62, 824) at  $160^{\circ}$ - $170^{\circ}$  for 3 hours, undergoes smooth decarboxylation to afford the keto-diester (III) imparting a deep red coloration to an alcoholic solution of ferric chloride. The keto-diester (III) is methylated by means of sodium dust in benzene and methyl iodide.

To study the spatial relationship of the two tertiary carboxyl groups attempts have been made to reduce the keto group in (IV) according to Wolff-Kishner method, but unfortunately, in spite of several attempts, the semicarbazone of the keto-diester could not be prepared, owing presumably to considerable steric hindrance.

The keto-diester (IV) is subjected to Reformatsky's reaction with zinc and ethyl bromoacetate according to the conditions laid down by Bachmann *et al.* (*loc. cit.*). The hydroxy-ester (V) is converted into the chloro derivative (VI) with thionyl chloride and pyridine, which on treatment with caustic potash undergoes unsaturation and hydrolysis giving an unsaturated anhydride (VII) on acidification. Reduction of the anhydride could not be effected by means of sodium amalgam. This has been reduced catalytically by means of platinum oxide in acetic acid when the reduced anhydride (VIII) is obtained in good yield.

The hydroxy-ester (V) is again treated with thionyl chloride and excess of pyridine when the unsaturated ester (IX) is obtained in good yield, which on catalytic reduction with  $PtO_2$  in acetic acid solution gives the reduced ester (X). The tri-ester on hydrolysis under drastic condition gives the reduced anhydride (VIII). In no case, however, could the tricarboxylic acid be isolated.

It is intended to prepare sufficient quantities of the acid anhydride (VIII) in order to investigate the possibility of its resolution.



#### EXPERIMENTAL

**Diethyl 1-Methylcyclohexan-2-one-1:3-dicarboxylate (III).**—Sodium dust (3 g.) was taken under dry ether (60 c. c.) and cooled. To this was added calcium-dried alcohol (6 g.) in drops and the mixture was left overnight. Ethyl oxalate (20 g.) was then added in the cold when the sodium derivative of the oxalic ester separated as light yellow crystals. The reaction mixture, after standing for 2 hours, was cooled in a freezing mixture (ice-salt,  $-15^{\circ}$ ) and ethyl 2-methylcyclohexanone-2-carboxylate (23 g.) was added dropwise with continuous shaking. Gradually the solid mass went into solution assuming a deep red colour. Then the mixture was kept in the ice-chest for 48 hours and diluted with cold water and extracted with ether to remove the unreacted products. The aqueous layer on acidification with ice-cold dilute sulphuric acid gave a thick, heavy layer at the bottom which was extracted with ether, the ethereal layer washed with sodium bicarbonate solution, water and then dried ( $\text{CaCl}_2$ ). After removal of the solvent the thick red liquid was heated at  $160^{\circ}$ - $170^{\circ}$  together with some powdered soft glass, until evolution of carbon monoxide ceased. It was then distilled in vacuum when the desired product passed over at  $142\text{--}45^{\circ}/6\text{ mm.}$ , yield 26 g. A drop of it imparted a deep red coloration to an alcoholic solution of ferric chloride. (Found: C, 61.15; H, 7.66.  $\text{C}_{13}\text{H}_{20}\text{O}_5$  requires C, 60.93; H, 7.81 per cent).

**Diethyl 1:3-Dimethylcyclohexan-2-one-1:3-dicarboxylate (IV).**—The above  $\beta$ -keto-ester (III, 25.6 g.) was added dropwise with shaking to sodium dust (2.7 g.) in 75 c. c. of dry benzene, cooled in ice-water. Gradually sodium went into solution which assumed a deep red colour. The mixture was allowed to stand overnight and then 20 c. c. of

methyl iodide added and refluxed for 2 hours on the water-bath. After diluting the cooled reaction mixture with water the benzene layer was separated, washed and dried. On removal of the solvent and distillation of the residue in *vacuo* 24 g. of the product (b. p.  $142^{\circ}/6$  mm.) were obtained which did not respond to ferric reaction. (Found: C, 61.86; H, 8.12.  $C_{14}H_{22}O_5$  requires C, 62.22; H, 8.15 per cent). Semicarbazone of (IV) could not be prepared in spite of several attempts.

*Ethyl 1:3-Dimethyl-1:3-dicarbethoxycyclohexane-2-ol-2-acetate* (V).—The above keto-diester (IV, 27 g.) was dissolved in thiophen-free benzene (50 c.c.) and to this was added 16 g. of zinc wool (washed with dilute hydrochloric acid, water and acetone, and dried before use), 12 c. c. of ethyl bromoacetate and 0.5 g. of iodine. As the mixture was refluxed on the water-bath, the colour of iodine faded and the solution became cloudy. After 10-15 minutes a vigorous reaction took place and a brown-coloured addition product was deposited. Four additions of 16 g. of zinc and a trace of iodine were made at 45 minutes' intervals and an additional 12 c. c. of ethyl bromoacetate was introduced after  $1\frac{1}{2}$  hours. The mixture was refluxed for a total of 4 hours. Frequently the mixture was vigorously shaken in order to free the zinc from the adhering mass of the deposit. The addition product was decomposed by adding acetic acid and methanol, and the solution decanted from the zinc into water and the mixture acidified with acetic acid and extracted with ether. The ether-benzene layer was separated, washed with water, then with dilute ammonia until no more colour was removed. The residue, obtained by evaporation of the dried ether benzene solution, was distilled when 17 g. of the desired product passed over at  $180-184^{\circ}/7$  mm. giving a blue fluorescence. (Found: C, 61.1; H, 8.52.  $C_{18}H_{30}O_6$  requires C, 60.3; H, 8.38 per cent). The analysis showed that the product consisted mainly of the hydroxy compound (V) contaminated with the corresponding unsaturated ester (IX).

*Dehydration of the Reformatsky Product.*—Thionyl chloride (12 g.) was slowly added with shaking to an ice-cold mixture of the above hydroxy-ester (V, 17 g.) and dry pyridine, which was then heated on the water-bath for 2 hours. The supernatant liquid was poured into ice and the solid mass decomposed with iced hydrochloric acid. The two solutions were combined and extracted with ether, the ethereal extract washed with dilute hydrochloric acid, water, sodium bicarbonate solution and again with water and then dried. After removal of the solvents distillation of the residue gave the desired compound containing much dissolved sulphur which was removed by refluxing with precipitated copper in benzene (50 c. c.) for 1 hour on the water-bath. After the removal of benzene from the filtered solution, the residue gave 12 g. of the unsaturated ester (IX), b. p.  $170-172^{\circ}/8$  mm. (Found: C, 63.36; H, 8.21;  $C_{18}H_{28}O_6$  requires C, 63.53; H, 8.23 p.c.).

*Ethyl 1:3-Dimethyl-1:3-dicarbethoxycyclohexane-2-acetate* (X).—The above unsaturated ester (IX, 12 g.) was hydrogenated in presence of platinum oxide catalyst (0.2 g.) in glacial acetic acid solution when a rather slow absorption of hydrogen took place. After the theoretical volume of hydrogen had been absorbed, the product was worked up in the usual manner when 11.5 g. of the saturated ester were obtained, b. p.  $165-67^{\circ}/6$  mm. (Found: C, 62.86; H, 8.62.  $C_{18}H_{30}O_6$  requires C, 63.15; H, 8.77 per cent).

*Anhydride of 1:3-Dimethyl-1:3-dicarboxycyclohexane-2-acetic Acid* (VIII).—The above tricarboxylic ester (X, 10 g.) was hydrolysed by boiling with a solution of caustic potash



(6.5 g.) in methyl alcohol (13 c. c.) for 10 hours, when the potassium salt of the tri-carboxylic acid was deposited. Water (5 c. c.) was added just to dissolve the precipitate and refluxing continued for 2 hours more. The cooled solution was then diluted with water and extracted with ether to remove unhydrolysed material. The alkaline extract was then acidified with dilute sulphuric acid when a clear solution was obtained. It was saturated with ammonium sulphate and extracted with ethyl acetate for several times. The combined ethyl acetate extract was washed with a little amount of water and dried over freshly calcined sodium sulphate. The solvent being removed by distillation the residue was evacuated at 5 mm. pressure when well defined crystals were deposited. On crystallisation from a little ethyl acetate it melted at 163-64°. (Found: C, 59.56; H, 6.52.  $C_{12}H_{10}O_5$  requires C, 60.00; H, 6.66 per cent). The mother-liquor on evaporation left a resinous mass which could not be solidified.

*The Unsaturated Anhydride (VII).*—The reformatsky product (V, 5 g.) was dissolved in dry benzene (5 c.c.) and dry pyridine (1 c.c.). To this was added with shaking in the cold 2 g. of thionyl chloride. After standing for 1 hour the mixture was evaporated under reduced pressure at room temperature and finally at 40°. The chloride was dissolved in 5 c. c. of benzene and decanted from the insoluble pyridine hydrochloride; the latter was digested several times with small portions of benzene and the extracts were added to the main portion. The solvent was then driven off and to the chilled residue was added 7 g. of caustic potash in 65 c.c. of methyl alcohol and the mixture refluxed for 15 minutes. Aqueous caustic potash solution (45%, 18 c.c.) was added to the cooled solution and refluxing continued. After an hour a large amount of precipitate was observed. Sufficient water was added to dissolve the precipitate and refluxing continued for 4 hours. After dilution the solution was extracted with ether to remove any unchanged material. The alkaline liquor was then acidified with ice-cold sulphuric acid, saturated with ammonium sulphate and extracted with ether for several times. The combined extract was washed with a little water, dried and the solvent removed. The residue after being kept under low pressure for some time solidified on addition of a drop or two of methyl alcohol. The solid was crystallised in clusters from glacial acetic acid, m.p. 146°. (Found: C, 60.36; H, 5.83.  $C_{12}H_{10}O_5$  requires C, 60.5; H, 5.88 per cent). The mother-liquor was evaporated, but the residue could not be solidified.

*Reduction of the Unsaturated Acid-anhydride (VII).*—The reduction of the above unsaturated anhydride (VII) was attempted with sodium amalgam (2%) according to the procedure of Bachmann. *et al* (*loc. cit.*) but curiously enough satisfactory results could not be obtained.

The unsaturated anhydride was then successfully reduced catalytically by means of platinum oxide catalyst in glacial acetic acid. The hydrogenated product was worked up in the usual way and crystallised from glacial acetic acid, m.p. 162° (mixed m. p. with the acid anhydride obtained by catalytic hydrogenation of the un-saturated tricarboxylic ester, IX followed by hydrolysis was 160-61°).

The author's thanks are due to Prof. P. C. Mitter for his valuable suggestions and encouragement during the course of this investigation and also to Mr. N. Ghosh for micro-analysis of some of the compounds.

PHYSICO-CHEMICAL STUDIES ON THE COMPOSITION OF COMPLEX  
METALLIC FERRO AND FERRICYANIDES. PART II.  
POTENTIOMETRIC STUDIES ON THE COMPOSITION OF COPPER FERROCYANIDE

ABANI K. BHATTACHARYA AND HARISH C. GAUR

The composition of copper ferrocyanide has been studied by conductometric method using ferriocyanide-ferrocyanide electrode. The composition closely approximates to  $K_4Cu_3[Fe(CN)_6]_2$ .

The composition of copper ferrocyanide has already been studied by the thermometric method of titration (Part I of this series, *this issue*, p. 487). In this paper use has been made of the ferricyanide-ferrocyanide electrode. The composition arrived at closely approximates to  $K_2Cu_3[Fe(CN)_6]_2$ , but is influenced by factors such as hydrolysis and adsorption.

According to the equation



the oxidation potential of the ferricyanide-ferrocyanide electrode is given by

$$E = E_0 + 0.059 \ln \frac{[Fe(CN)_6]^{III}}{[Fe(CN)_6]^{II}} \quad (\text{at } 25^\circ).$$

In the titration of copper sulphate solution with potassium ferrocyanide solution containing a little ferricyanide (Galetti, *Bull. Soc. chim.*, 1864, *ii*, 2, 83; *Z. anal. Chem.*, 1865, *4*, 213) so long as there is an excess of copper ions in the solution, the concentration of ferrocyanide is small and so the potential of the electrode is high. As soon as the copper ions are quantitatively precipitated, the next drop of ferrocyanide solution causes a sudden increase in  $[Fe(CN)_6]^{II}$ , and hence a sudden decrease in the oxidation potential occurs. The equivalence point may therefore be detected.

#### EXPERIMENTAL

In all the titrations potassium ferrocyanide containing 1% potassium ferricyanide was used (Kolthoff-Kolthoff and Furman, "Potentiometric Titrations"). Electrode used was of platinised platinum (Muller, *Z. physikal. Chem.*, 1914, 88, 44), which was used in conjunction with the saturated calomel electrode. Graphs were plotted between  $E(\text{obs.})$  against the volume of ferrocyanide added.

'Analar' (B. D. H.) reagents were used, and standard solutions were prepared as described in Part I of this series (*loc. cit.*).

$M/5$  solution of potassium ferrocyanide would be referred as A/1 solution and  $M/4.85$  solution of copper sulphate, as A/1 of copper sulphate solution.

TABLE I

A/4-CuSO<sub>4</sub> soln.=20 c.c. (Fig. 1, curve 1).

A/2- K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/2- K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/2- K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/2- K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/2- K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)
0 0 c.c.	0 4581 volt	3 4 c.c.	0 4031 volt	4 8 c.c.	0 3570 volt	6 2 c.c.	0 3960 volt	7 6 c.c.	0 1741 volt
1.0	0 4428	3 6	0 3919	5 0	0 3543	6 4	0 3975	7 8	0 1690
1 5	0 4347	3 8	0 3863	5 2	0 3410	6 6	0 2901	8 0	0 1649
2.0	0 4286	4 0	0 3807	5 4	0 3319	6 8	0 2616	8 5	0 1578
2.5	0 4215	4 2	0 3751	5 6	0 3278	7 0	0 2117	9 0	0 1517
3.0	0 4133	4 4	0 3700	5 8	0 3367	7 2	0 1934	9 5	0 1466
3 2	0 4087	4 6	0 3640	6 0	0 3777	7 4	0 1812	10 0	0 1425

TABLE II

A/2-CuSO<sub>4</sub> soln.=20 c.c. (Fig. 1, curve 2).

A/2 K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/2 K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/2 K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/2 K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)
0 0 c.c.	0 4581 volt	9 4 c.c.	0 3975 volt	12 0 c.c.	0 3990 volt	15 0 c.c.	0 1843 volt
1.0	0 5161	9 6	0 3924	12 2	0 3950	15 5	0 1787
2.0	0 5187	9 8	0 3864	12 4	0 3900	16 0	0 1720
3.0	0 5192	10 0	0 3797	12 6	0 3820	16 5	0 1664
4.0	0 5125	10 2	0 3706	12 8	0 3625	17 0	0 1629
5.0	0 4825	10 4	0 3634	13 0	0 3268	17 5	0 1598
6.0	0 4561	10 6	0 3532	13 2	0 2962	18 0	0 1573
7 0	0 4398	10 8	0 3431	13 4	0 2596	18 5	0 1547
7 5	0 4321	11 0	0 3340	13 6	0 2362	19 0	0 1527
8 0	0 4225	11 2	0 3324	13 8	0 2220	19 5	0 1512
8 5	0 4180	11 4	0 3349	14 0	0 2118	20 0	0 1492
9 0	0 4097	11 6	0 3461	14 2	0 2036		
9 2	0 4021	11 8	0 3828	14 5	0 1955		

TABLE III

A/10-CuSO<sub>4</sub> soln.=20 c.c. (Fig. 2, curve 3).

A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)
0 0 c.c.	0 4092 volt	4 7 c.c.	0 2688 volt	6 9 c.c.	0 1446 volt
0 5	0 3889	4 9	0 2748	7 1	0 1415
1 0	0 3807	5 0	0 3032	7 3	0 1385
1 5	0 3721	5 1	0 2667	7 5	0 1354
2 0	0 3604	5 3	0 2479	7 7	0 1344
2 5	0 3522	5 5	0 2194	7 9	0 1323
3 0	0 3451	5 7	0 1888	8 1	0 1308
3 5	0 3354	5 9	0 1746	8 3	0 1293
3 7	0 3268	6 1	0 1649	8 5	0 1273
3 9	0 3207	6 3	0 1578	8 7	0 1262
4 1	0 3110	6 5	0 1527	8 9	0 1252
4 3	0 2962	6 7	0 1481	9 1	0 1237
4 5	0 2718				

TABLE IV

A/4-CuSO<sub>4</sub> soln.=20 c.c. (Fig. 2, curve 4).

A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)	A/4-K <sub>4</sub> FeCy <sub>6</sub> added.	E(obs.)
0.0 c.c.	0.4164 volt.	10.0 c.c.	0.3527 volt	14.0 c.c.	0.2168 volt.
1.0	0.4143	10.6	0.3344	14.2	0.2031
2.0	0.4113	11.0	0.3191	14.4	0.1929
3.0	0.4082	11.5	0.3181	14.6	0.1883
4.0	0.4042	11.7	0.3237	14.8	0.1838
5.0	0.4011	12.0	0.3431	15.0	0.1802
6.0	0.3960	12.4	0.3573	15.5	0.1710
7.0	0.3914	12.6	0.3482	16.0	0.1649
8.0	0.3848	12.8	0.3410	16.5	0.1598
8.5	0.3807	13.0	0.3280	17.0	0.1558
9.0	0.3756	13.2	0.3105	17.5	0.1527
9.2	0.3695	13.4	0.2952	18.0	0.1502
9.4	0.3644	13.6	0.2718	18.5	0.1471
9.6	0.3694	13.8	0.2372	19.0	0.1445
9.8	0.3568			19.5	0.1440
				20.0	0.1430

TABLE V

*Results of the potentiometric titrations.*

Curve No.	K <sub>4</sub> Fe(CN) <sub>6</sub> .	CuSO <sub>4</sub> .	Obs. titre value for 20 c.c. of CuSO <sub>4</sub> soln.	Equiv. vol. of K <sub>4</sub> FeCy <sub>6</sub> of same strength.
1	A/2	A/4	6.65 c.c.	13.30 c.c.
2	A/2	A/2	13.20	13.20
3	A/4	A/10	5.30	13.25
4	A/4	A/4	13.50	13.50

## DISCUSSION

Considering the strenghts of the copper sulphate (*M*/4.85) and potassium ferrocyanide (*M*/5.0) solutions, the theoretical titre values for 20 c.c. of copper sulphate solution for the formations of the compounds K<sub>2</sub>CuFe(CN)<sub>6</sub>, Cu<sub>2</sub>Fe(CN)<sub>6</sub>, and K<sub>2</sub>Cu<sub>3</sub>[Fe(CN)<sub>6</sub>]<sub>2</sub> are 20.62, 10.31, and 13.75 c.c. respectively.

The observed titre values, which correspond to the sudden fall in potential in the latter part of the curve, are slightly lower than the theoretical ones required for the formation of the compound K<sub>2</sub>Cu<sub>3</sub>[Fe(CN)<sub>6</sub>]<sub>2</sub>. Kolthoff and Furman (*loc. cit.*), and Müller and Takagami (*Z. anal. Chem.*, 1928, 73, 284) also observed that the maximum leap in potential did not occur at the required point of equivalence.

The discrepancy between the observed and the theoretical titre values can be explained on the tendency of the compound formed to hydrolyse. The phenomenon of hydrolysis has already been shown to play an important role in the precipitation of this compound (Part I of this series). Then potassium ferrocyanide, thus released, will react with some copper sulphate solution, with the result that the observed titre values would be lower than the theoretical values required.

FIG. 1

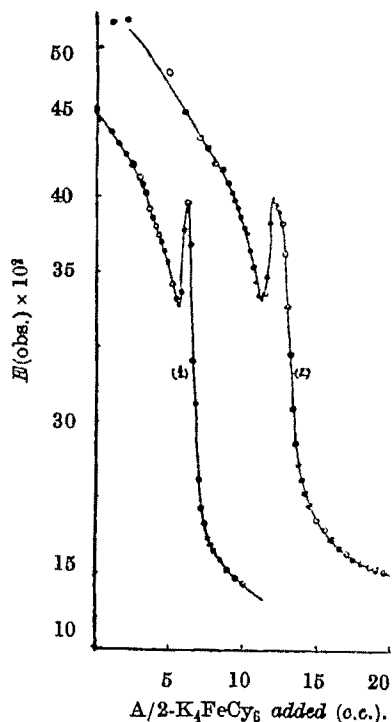
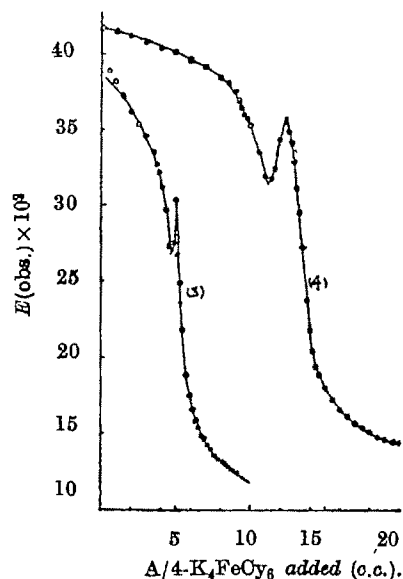


FIG. 2



The adsorption of copper ions by copper ferrocyanide sol has also been observed. This would also tend to lower the titre value. It seems that these facts were not taken into consideration by Kolthoff and Furman, and by Müller and Takagami.

In the loop obtained in the first part of the curve, the first decrease in E. M. F. is evidently due to the increase in concentration of the  $[\text{Fe}(\text{CN})_6]^{4-}$  ions, released by copper ferrocyanide. The latter portion *i.e.* the rise in the curve is probably due to the adsorption of the  $[\text{Fe}(\text{CN})_6]^{4-}$  ions from the solution.

The titrations could not be followed in the presence of alcohol (*vide* Part I of the series) as constant values of potential could not be obtained to assure reproducibility of results. It is, however, difficult to explain with certainty the actual cause of similar loops which appear in each titration curve. Hydrolysis and adsorption phenomena disturbing the equilibrium of the ratio of

$$\frac{[\text{Fe}(\text{CN})_6]^{3-}}{[\text{Fe}(\text{CN})_6]^{4-}} \text{ seem to be responsible for this observation.}$$

Thanks of the authors are due to Dr. S. S. Deshapande for the interest he has taken in these investigations. One of the authors (H. C. Gaur) expresses his gratefulness to Dr. K. C. Mehta, Principal, Agra College, for the extension of a research fellowship.

# STUDIES ON COMPLEX CARBONATES OF URANIUM BY THERMOMETRIC AND CONDUCTOMETRIC METHODS

BY BARUN CHANDRA HALDAR

Both thermometric and conductometric methods indicate the existence in solution of the compounds of the type  $R_4UO_2(CO_3)_3$  and  $R_2UO_2(CO_3)_2$  (where  $R=Na$  or  $K$ ).

Literature on complex carbonates of uranium with alkali carbonates shows only the existence of the compounds  $K_4UO_2(CO_3)_3$  (Aloy, *Ann. chim. phys.*, 1901, vii, 24, 412; Ebelmen, *ibid.*, 1842, vii, 5, 189) and  $Na_4UO_2(CO_3)_3$  (Anthon, *Dingl. poly. J.*, 1860, 156, 207, 288) but no mention of the compounds of the type  $R_2UO_2(CO_3)_2$  (where  $R=Na$  or  $K$ ) is found. It is expected from the very close analogous behaviour of the uranyl radical ( $UO_2^{++}$ ) with other bivalent transitional metals that it should also have a compound of the type  $R_2UO_2(CO_3)_2$  or  $R_2CO_3.UO_2.CO_3$  as in the case of other bivalent transitional metals reported by Reynold (*J. Chem. Soc.*, 1898, 73, 263) and others. In the present investigation attempts have been made to obtain indications of the existence of the compounds  $K_2UO_2(CO_3)_2$  and  $Na_2UO_2(CO_3)_2$  by physico-chemical methods such as thermometric and conductometric titrations of uranyl salts with alkali carbonate solutions and *vice versa*.

## EXPERIMENTAL

The thermometric arrangement is the same as that has been described in a previous paper (Haldar, *J. Indian Chem. Soc.*, 1946, 23, 147).

*Conductivity Apparatus.*—The arrangement is in principle a Wheatstone bridge. The A. C. was provided by a valve oscillator of the Hartley type giving an accurately determined frequency, free from harmonics. The sharpness of the minimum was increased by replacing the telephone by a vacuum tube amplifier. The earphone was then connected in the plate circuit of the vacuum tube.

Uranyl nitrate solution was estimated as  $U_3O_8$  by evaporating 10 c.c. of the solution in a platinum crucible on a water-bath and the residue was then heated in a full flame of the Meker burner until the weight of the crucible was constant. Alkali nitrate solutions were estimated as sulphate. All conductometric titrations were carried out in an electrically controlled thermostat, the temperature of which could be adjusted correct to  $0.1^\circ$ . Solutions for conductometric titrations were prepared in twice-distilled water.

*Thermometric Titrations*

TABLE I

Uranyl nitrate soln. = 0.4100*M* ; 40 c.c. of 0.0202*M*-Na<sub>2</sub>CO<sub>3</sub> soln.

Uranyl nitrate soln. added.	Temp.	Rise in temp	Total rise in temp.	Uranyl nitrate soln. added.	Temp.	Rise in temp.	Total rise in temp
0 c.c.	4.030	0.000	0.000	11 c.c.	3.570	-0.07	0.465
1	3.950	.080	.080	12	.640	-.070	.395
2	.860	.090	.170	13	.710	-.070	.325
3	.765	.095	.265	14	.790	-.080	.325
4	.680	.080	.345	16	.920	-.130	.245
5	.600	.080	.425	18	.965	-.045	.115
6	.520	.080	.505	20	.955	+.010	.070
7	.495	.035	.540	22	.945	+.010	.080
8	.495	.000	.540	24	.925	+.020	.090
9	.495	.000	.540	26	.905	+.020	.110
10	.500	-0.005	.535				.130

TABLE II

Uranyl nitrate soln. = 0.205*M* ; 40 c.c. of 0.101*M*-Na<sub>2</sub>CO<sub>3</sub> soln.

Uranyl nitrate soln. added.	Temp.	Rise in temp.	Total rise in temp.	Uranyl nitrate soln. added.	Temp.	Rise in temp.	Total rise in temp.
0 c.c.	3.990	0.000	0.000	10.0 c.c.	3.720	0.000	0.270
1	.950	.040	.040	11.0	.750	-0.030	.240
2	.900	.050	.090	12.0	.780	-.030	.210
3	.860	.040	.130	13.0	.810	-.030	.180
4	.820	.040	.170	14.0	.840	-.030	.150
5	.775	.045	.215	16.0	.900	-.060	.090
6	.730	.045	.260	18.0	.920	-.020	.070
6.5	.720	.010	.270	20.0	.920	-.000	.070
7.0	.720	.000	.270	22.0	.910	.010	.080
8.0	.720	.000	.270	24.0	.900	.010	.090
9.0	.720	.000	.270	26.0	.890	.010	.100
9.5	.720	.000	.270				

TABLE III

Na<sub>2</sub>CO<sub>3</sub> soln. = 0.9807*M* ; 40 c.c. of 0.1004*M*-Uranyl nitrate soln.

Vol. Na <sub>2</sub> CO <sub>3</sub> soln. added	Temp.	Rise in temp	Total rise in temp	Vol. Na <sub>2</sub> CO <sub>3</sub> soln. added	Temp.	Rise in temp	Total rise in temp
0 c.c.	2.100	0.000	0.000	10 c.c.	1.935	0.035	0.165
1	.180	-.080	-.080	11	.910	.025	.190
2	.240	-.060	-.140	12	.880	.030	.220
3	.285	-.045	-.185	13	.865	.015	.235
4	.320	-.035	-.220	14	.850	.015	.250
5	.320	-.000	-.220	16	.820	.030	.280
6	.215	.105	-.115	14	.805	.015	.295
7	.115	.100	-.015	20	.790	.015	.310
8	.040	.075	.060				
9	1.970	.070	.013				

TABLE IV

Uranyl nitrate soln. = 0.1942*M* ; 40 c.c of 0.08786*M*-K<sub>2</sub>CO<sub>3</sub> soln.

Vol. of uranyl nitrate soln. added	Temp	Rise in temp.	Total rise in temp.	Vol. of uranyl nitrate soln. added.	Temp.	Rise in temp.	Total rise in temp
0 c.c.	4.530	0.000	0.000	10 c.c.	4.290	-0.01	0.240
1	.490	.040	.040	11	.310	-0.02	.220
2	.440	.050	.090	12	.340	-0.03	.190
3	.390	.050	.140	13	.370	-0.03	.160
4	.350	.040	.180	14	.395	-0.025	.136
5	.305	.045	.225	16	.420	-0.025	.110
6	.280	.025	.250	18	.430	-0.010	.100
7	.280	.000	.250	20	.430	-.00	.100
8	.280	.000	.250	22	.430	-.00	.100
9	.280	.000	.250				

TABLE V

Uranyl nitrate soln. = 0.38835*M* ; 40 c.c. of 0.1757*M*-K<sub>2</sub>CO<sub>3</sub> soln.

Vol. uranyl nitrate soln. added.	Temp.	Rise in temp.	Total rise in temp.	Vol. uranyl nitrate soln. added.	Temp.	Rise in temp.	Total rise in temp.
0 c.c.	3.860	0.000	0.000	9 c.c.	3.485	-0.020	0.375
1	.790	.070	.070	10	.495	-.010	.365
2	.715	.075	.145	11	.520	-.025	.340
3	.640	.075	.220	12	.540	-.020	.320
4	.570	.070	.290	13	.550	-.010	.310
5	.500	.070	.360	14	.565	-.015	.295
6	.450	.050	.410	16	.620	-.055	.240
7	.450	.000	.410	18	.710	-.090	.150
8	.465	-.015	.395	20	.790	-.080	.070

TABLE VI

K<sub>2</sub>CO<sub>3</sub> soln. = 1.5254*M* ; 40 c.c. of 0.1942*M*-Uranyl nitrate soln.

K <sub>2</sub> CO <sub>3</sub> soln. added.	Temp.	Rise in temp.	Total rise in temp	K <sub>2</sub> CO <sub>3</sub> soln. added.	Temp.	Rise in temp.	Total rise in temp.
0 c.c.	4.230	0.000	0.000	10 c.c.	3.640	0.110	0.590
1	.300	-.070	-.070	11	.520	.120	.710
2	.340	-.040	-.110	12	.450	.070	.780
3	.350	-.010	-.120	13	.400	.050	.830
4	.350	-.000	-.120	14	.360	.040	.870
5	.330	.020	-.100	15	.320	.040	.910
6	.270	.060	-.040	16	.290	.030	.940
7	.065	.205	.165	18	.220	.070	1.010
8	.880	.185	.350	20	.170	.050	1.060
9	.750	.130	.480	22	.120	.050	1.110



TABLE VII

$K_2CO_3$  soln. = 0.78705M ; 40 c.c. of 0.09709M-Uranyl nitrate soln.

$K_2CO_3$ soln. added.	Temp.	Rise in temp.	Total rise in temp.	$K_2CO_3$ soln. added.	Temp.	Rise in temp.	Total rise in temp.
0 c.c.	4.580	0.000	0.000	10 c.c.	4.135	0.080	0.445
1	.590	— .010	— .010	11	4.040	.095	.540
2	.605	— .015	— .025	12	3.990	.050	.59
3	.605	— .000	.025	13	.950	.040	.63
4	.580	.025	.000	14	.015	.035	.665
5	.555	.025	.025	15	.885	.030	.695
6	.510	.045	.070	16	.855	.030	.725
7	.410	.100	.170	18	.800	.055	.78
8	.310	.100	.270	20	.750	.050	.83
9	.215	.095	.365	22	.710	.040	.87

*Conductometric Titrations*

TABLE VIII

Uranyl nitrate soln. = 50 c.c. of 0.0103M ;  $Na_2CO_3$  soln. = 2M. Temp. =  $27^\circ \pm .1^\circ$

$Na_2CO_3$ soln. added.	$1/R \times 10^4$	$Na_2CO_3$ soln. added.	$1/R \times 10^4$	$Na_2CO_3$ soln. added.	$1/R \times 10^4$	$Na_2CO_3$ soln. added.	$1/R \times 10^4$
0 c.c.	103 mho	0.280 c.c.	105.1 mho	0.530 c.c.	158.4 mho	0.795 c.c.	236.1 mho
0.05	98	.320	109.7	.575	171.5	.840	249.3
.12	99	.360	117.0	.620	184.5	.930	272.5
.16	99.9	.405	127.5	.665	194.9	1.015	284.9
.20	101.7	.450	138.5	.710	209.2	1.100	305.9
.235	103.9	.490	146.6	.750	223.7		

TABLE IX

Uranyl nitrate soln. = 0.5M. 50 c.c. of 0.01M- $K_2CO_3$  soln. = Temp. =  $27^\circ \pm .1^\circ$

Uranyl nitrate soln. added	$1/R \times 10^4$	Uranyl nitrate soln. added.	$1/R \times 10^4$	Uranyl nitrate soln. added.	$1/R \times 10^4$
0.0 c.c.	118.3 mho.	0.465 c.c.	101.0 mho.	0.740 c.c.	104.0 mho.
.99	114.8	.510	101.4	.840	111.1
.185	111.1	.560	101.4	.935	119.7
.275	107.5	.605	102.2	1.020	128.2
.370	102.7	.650	102.2	1.110	136.7
.415	101.4	.695	102.7	1.200	144.7

TABLE X

Uranyl nitrate soln. = 50 c.c. of 0.01 M.  $K_2CO_3$  soln. = 2 M. Temp. =  $27^\circ \pm .1^\circ$

$K_2CO_3$ soln. added.	$1/R \times 10^4$	$K_2CO_3$ soln. added	$1/R \times 10^4$	$K_2CO_3$ soln. added.	$1/R \times 10^4$	$K_2CO_3$ soln. added	$1/R \times 10^4$
0.0 c.c.	104.0 mho	0.245 c.c.	123.8 mho.	0.510 c.c.	196.3 mho.	0.845	328.3 mho.
.075	105.3	.320	134.6	.585	225.2	.920	356.6
.150	112.7	.395	156.7	.655	254.2	1.025	394.0
.220	121.2	.465	179.2	.750	290.6	1.120	430.8

TABLE XI

Uranyl nitrate soln. = 0.5M ; 50 c.c. of 0.01 M-Na<sub>2</sub>CO<sub>3</sub> soln. Temp. = 27° ± .1°

Uranyl nitrate soln. added.	1/R × 10 <sup>4</sup> .	Uranyl nitrate soln. added.	1/R × 10 <sup>4</sup>	Uranyl nitrate soln. added.	1/R × 10 <sup>4</sup> .
0.00 c.c.	99.2 mho.	0.395 c.c.	89.3 mho.	0.675 c.c.	99.0 mho.
.08	97.3	.440	89.1	.770	91.3
.17	95.6	.490	89.2	.860	98.9
.26	93.2	.540	89.3	.950	102.9
.305	92.0	.580	89.2	1.045	110.8
.355	90.4	.630	89.8	1.230	125.9
				1.405	140.8

TABLE XII

Uranyl nitrate soln. = 50 c.c. of 0.01M. KNO<sub>3</sub> soln. = 1 M. Temp. = 27° ± .1°

KNO <sub>3</sub> soln. added	1/R × 10 <sup>4</sup> .	KNO <sub>3</sub> soln. added.	1/R × 10 <sup>4</sup> .	KNO <sub>3</sub> soln. added.	1/R × 10 <sup>4</sup> .	KNO <sub>3</sub> soln. added.	1/R × 10 <sup>4</sup> .
0 0 c c.	104.7 mho.	0.790	166.0 mho.	0.885 c c.	210.01 mho.	1.380 c.c.	265.3 mho.
.105	117.0	.580	177 0	1.015	223 02	1.510	278.6
.240	134.2	.700	190.5	1.135	234.58	1.690	299.9
.335	145.4	.795	202.3	1.260	253.31	1.840	317.4
						1.990	331 4

TABLE XIII

Uranyl nitrate soln. = 50 c.c. of 0.01M. NaNO<sub>3</sub> soln. = 1M. Temp. 27° ± .1°

NaNO <sub>3</sub> soln. added	1/R × 10 <sup>4</sup> .	NaNO <sub>3</sub> soln. added	1/R × 10 <sup>4</sup> .	NaNO <sub>3</sub> soln. added	1/R × 10 <sup>4</sup> .	NaNO <sub>3</sub> soln. added.	1/R × 10 <sup>4</sup> .
0.0 c c	mho.	0.520 c c.	139.1 mho.	1.010 c.c.	191.9 mho.	1.680 c.c.	248.1 mho.
.110	105.8	.660	155.2	1.190	202.6	1 850	265.3
.220	115.5	.790	169.0	1.320	219.6	1.995	331.0
.350	126.6	.900	181.9	1.500	232.7		294 0

## DISCUSSION

It is evident from the curves shown below that carbonates of the type  $R_1UO_3(CO_3)_3$  and  $R_2UO_3(CO_3)_2$  both exist. The breaks in the thermometric curves appear at the

FIG. 1.

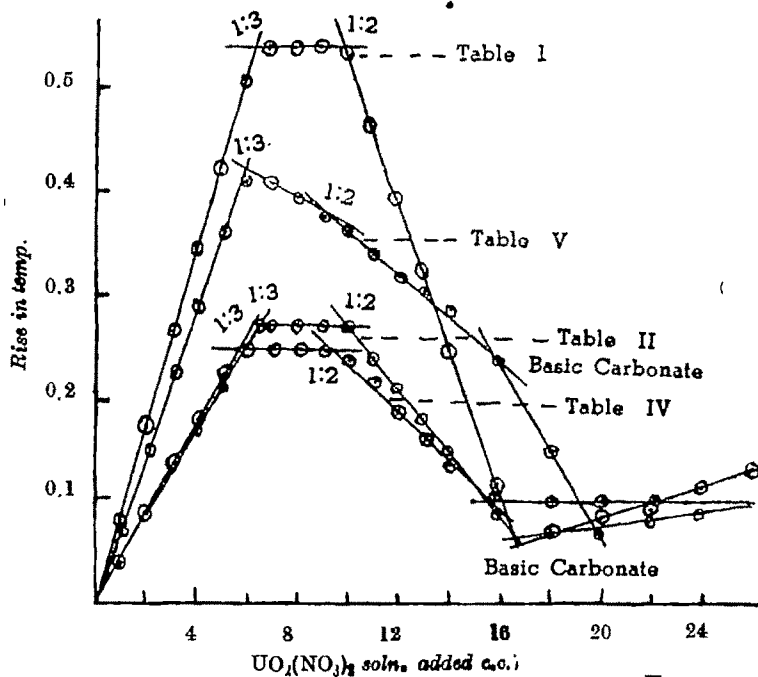


FIG. 2.

FIG. 3.

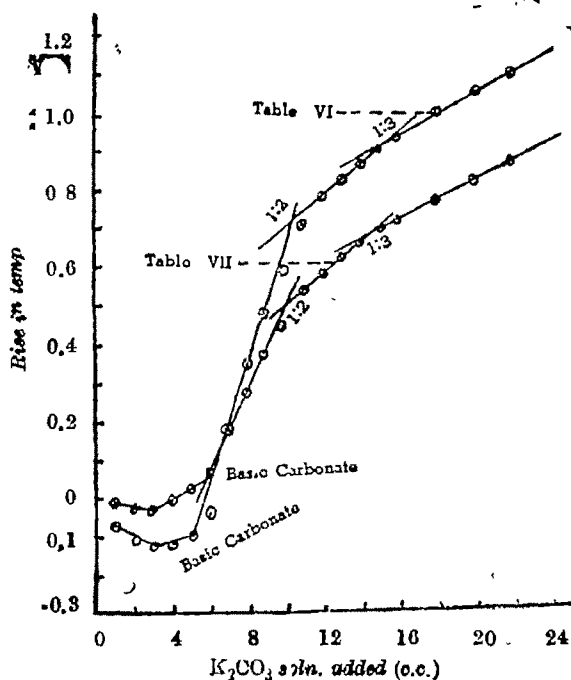
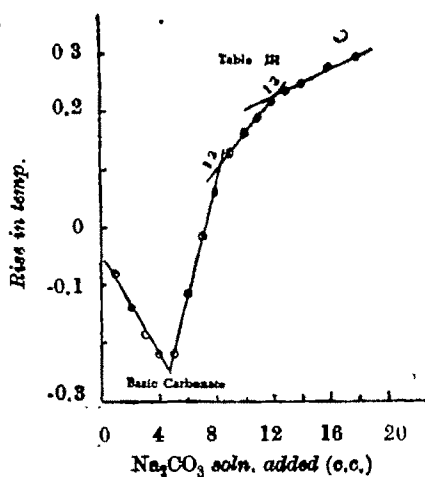


FIG. 4.

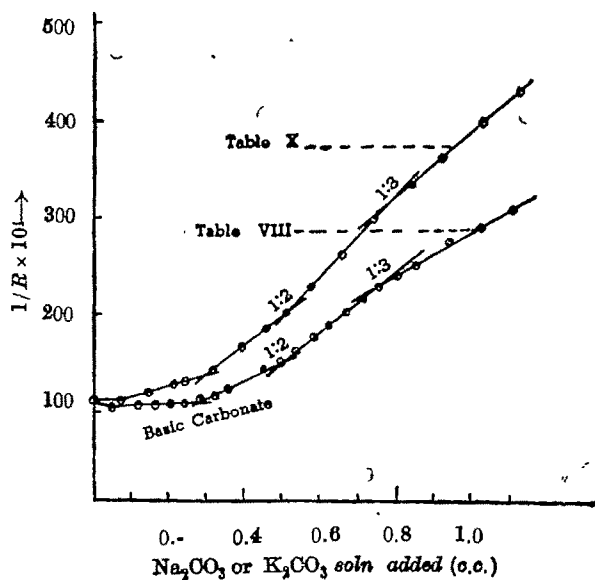


FIG. 5.

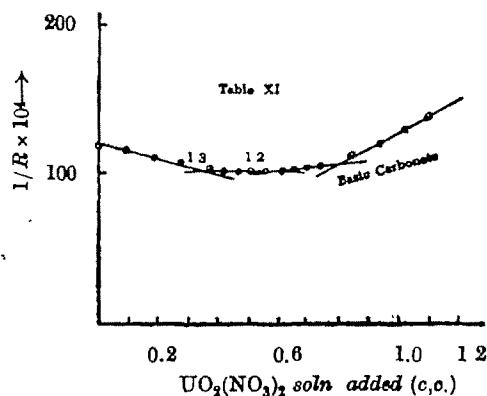


FIG. 6.

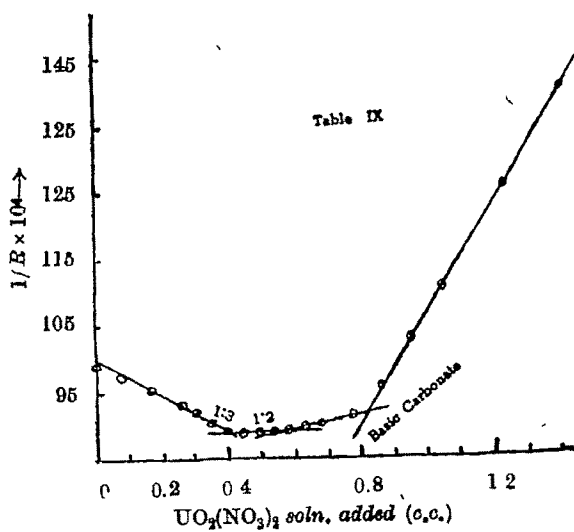
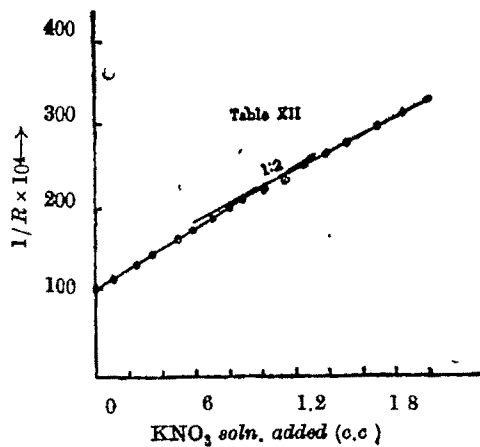
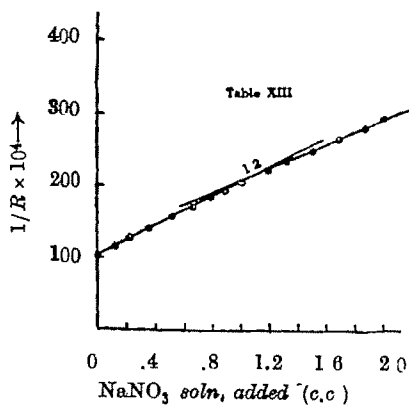


FIG. 7.



points corresponding to uranyl nitrate : alkali carbonate equal to 1:3 and 1:2 over

FIG. 8.



the concentration range studied. Moreover, the breaks are always obtained at the same points either by adding alkali carbonate solutions to uranyl nitrate solutions or *vice versa*. In conductometric titration curves, breaks corresponding to  $R_4UO_2(CO_3)_3$  and  $R_2UO_2(CO_3)_2$  appear exactly at the equivalent points only when the alkali carbonate solutions are added to uranyl nitrate solutions (Fig 4). But in reverse titrations i.e., when uranyl nitrate solutions are added to alkali carbonate solutions (Fig. 5-6), the two breaks are not exactly at the points corresponding to  $R_4UO_2(CO_3)_3$  and  $R_2UO_2(CO_3)_2$  but slightly shifted. The exact cause of the shifting in the curves (Fig. 5-6)

is difficult to say with certainty but it may be due to the complex nitrate formation. Conductometric titrations of uranyl nitrate with alkali nitrates show indication of complex formation of the type  $R_2UO_2(NO_3)_4$  where  $R=Na$  or  $K$ . Although the breaks in curves (Fig.7-8) are not very sharp, they are always found to occur at the point corresponding to uranyl nitrate : alkali nitrate equal to 1:2. Literature on complex nitrates of uranium nitrate with alkali nitrates describe only the potassium compound  $K_2UO_2(NO_3)_4$  and not the sodium compound. However, to explain the discrepancy observed in the curves 9 and 11 and the difference in the slopes of the curves 4 and 5, further investigation is needed

Break due to basic carbonate of indefinite composition is also found to occur in the curves (Fig. 1-5).

Thus with thermometric and conductometric evidences on the existence of the carbonates of the type  $R_2UO_2(CO_3)_2$ , the uranyl radical ( $UO_3$ ) shows close analogy with other bivalent transitional metals particularly with respect to complex carbonate formation.

The author's best thanks are due to Prof. P. B. Sarkar, Dr. Es. Sc., F.N.I., for his keen interest, helpful suggestions and all laboratory facilities during the progress of the work.

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## REVIEWS

**Organic Chemistry**—By Paul Karrer, Professor at the University of Zurich. Translated by A. J. Mee, Head of the Science Department, Glasgow Academy. Second English Edition, 1946; based on the eighth German edition. Published by the Elsevier Publishing Company, Inc., New York. Page 953+xx. Price \$7.50.

It is one of the standard text-books of organic chemistry, which is of immense service both to students and teachers of organic chemistry. The book has been divided into four parts. Part I deals with the aliphatic compounds which have been arranged according to their functional groups (monovalent, divalent functions etc, halogen function, hydroxyl function etc.). Part II deals with the carbocyclic compounds, the aromatic and the alicyclic compounds and in the latter section the chemistry of the sesquiterpenes, polyterpenes, the sterols, the vitamins have been discussed. Part III deals with the heterocyclic compounds and in this part there are two sections—section I treats simpler heterocyclic compounds with more or less aromatic nature and in section II, the chemistry of the alkaloids has been discussed. In Part IV the organic compounds with heavy hydrogen and heavy oxygen have been dealt with. The book gives a survey of the ever-increasing body of facts and in addition to the ordinary topics, the chemistry of naturally occurring substances and of substances of biochemical interest has been particularly emphasised. The references to original journals and a large number of tables appended to the book, have increased the usefulness of the book.

D. C.

**Chemotherapy yesterday, to-day and tomorrow**—The Linacre Lecture 1946—By Sir Alexander Fleming. Published by the Cambridge University Press. Price 2/-Sh. net.

The discoverer of Penicillin has described in the pamphlet the chemotherapy of bacterial diseases by means of various drugs, discovery of penicillin, its applications and properties. Sir Alexander Fleming has pointed out how the spectacular success of penicillin has stimulated the most intensive research into other antibiotics e.g. streptomycin. Lastly, he has put forward a powerful plea for the speedy endowment of microbiological research.

D. C.

**Physical Methods of Organic Chemistry: Vol. II**—Edited by Arnold Weissberger. Published by the Interscience Publishers, Inc., New York. 1946. Pp-737-1367+vi. Price \$8 50.

All scientific progress is an advancement in technique which depends largely on finding new things for doing and the discovery of better ways of doing old things. The development of proper technique for investigation in a particular branch of science is therefore an essential prerequisite. Physical science has developed much in that respect, its technique has also found wider application in other branches of science with very fruitful results. It is therefore natural that Organic Chemistry with the increasing number and complexity of its problems will depend more on physical methods and techniques for their better handling and accuracy of results, but it is very difficult for an individual chemist to acquaint himself with the various methods of physical sciences which he may be required to employ in course of his own work. This task becomes all the more difficult, if he is to look for those methods scattered over different periodicals and literatures. The book under review has been compiled with the

hope of relieving the chemist much of this burden. It also deals with various physical methods of which particular mention may be made of spectroscopy, polarography, and mass spectrometry. Besides, a description of the essentials of the methods, a theoretical background for understanding and handling them have been provided in this book. It contains a good bibliography which will prove very useful to organic chemists depending on physical methods for working out their problems.

S. R.

**Currents in Biochemical Research**—Edited by David E. Green. Published by the Interscience Publishers Inc., New York 1946. Pages 486 + vi. Price \$5.0.

The volume under review is a compilation of some thirty essays by well known authorities in Biochemistry and borderland subjects. These essays represent the main developments in those fields with indications for the most likely paths of future progress. According to the editor these essays have been intended "to excite the imagination and provide glimpses of some of the fascinating horizons of biochemical research." That purpose has undoubtedly been fulfilled in this volume which covers a wide variety of subjects such as pharmacology, chemotherapy, public health, genetics, photosynthesis, besides the more important biochemical topics including enzymes, vitamins, hormones etc. Some essays have also been devoted to the application of physical methods in biochemistry such as tracer technique, X-ray diffraction etc., which have recently revolutionised the biochemical science. The book will surely assist biochemists, chemists and medical men in viewing biochemistry in clearer perspective and in its proper relation to other branches of science. It will also acquaint them with the real "current" and not "eddies" in the biochemical thought.

S. R.

**The Terpenes : Vol I**—By J. L. Simonsen. Second Edition revised by J. L. Simonsen and L. N. Owen. Demy 8 vo ; 479 pages. Published by the University Cambridge Press. Price 30/- Sh.

Present day students of Organic Chemistry will no doubt accord the same warm welcome to the Second Edition of Terpenes Vol I by J. L. Simonsen as their predecessors gave to the first edition of this admirable book, in 1931. They will also eagerly look forward to an early publication of the Second Volume.

The book which could have been aptly begun by the author with the phrase "quorum pars magna fui" should find a place on the book-shelf of every English-speaking students of Organic Chemistry.

**Selected Topics from Organic Chemistry**—By D. D. Karve and G. D. Advani. Published by Dastane Brothers' Home Service, Poona. Pp. 1-184.

The book is intended for the use of students preparing for their degree examinations. There are thirty chapters in this volume and each chapter deals with a particular topic, which is usually in the curriculum for the degree examinations. The authors have always been brief and concise referring to the salient points and omitting in many cases the essential details. The volume may be used by the students with advantage as a guide book for their examination.

D. C.

## OBITUARY

NAGENDRA NATH SEN-GUPTA

Born: November 10, 1895

Died: July 27, 1947.

Nagendra Nath Sen-Gupta was the fourth son of late Mr. Krishna Jibon Sen-Gupta, a zamindar of Noakhali. He had his college education at the Presidency College, but on account of his political activities he had to leave India. He took his admission in the Armstrong College, New Castle. He obtained his M. Sc. degree in Agricultural Chemistry from the Durham University. On returning to India he joined a Missionary College at Allahabad as a Professor of Chemistry. In 1925 he joined the Government Test House, Alipore, Calcutta as a chemist. His intellectual brilliance and keen sense of duty gradually earned for him the position of the Director of the Institution.

As an officer of the Government Test House he came in close touch with various industrial concerns and acquired an intimate knowledge of various types of commercial and industrial products. The knowledge, which he thus acquired was profitably utilised by his appointment as a member of various official and non-official committees, e.g., Chemists and Metallurgists Standing Committee, Jute Research Committee, National Physical Laboratory Committee, etc. He was one of the founders of the Institution of Chemists (India) and was the author of several scientific publications of industrial importance, e.g.

Heavy Chemical Industries in India  
Industries on the Banks of the Hoogly  
Camouflage Paints

He led a very simple and abstemious life and had an unassuming disposition. In office he was a strict disciplinarian. He had been ailing for sometime in Calcutta and went to Bijapur for a change where he breathed his last on July 27, 1947.

By his untimely death the Society has lost one of its Foundation Fellows and the Government of India, a brilliant and able administrator.

D. S. N.